# PLANT PATHOLOGY

## A RECORD OF CURRENT WORK ON PLANT DISEASES AND PESTS

*Published quarterly for the*
*Ministry of Agriculture, Fisheries and Food*
*Plant Pathology Laboratory*
*Harpenden, Herts*

VOLUME 8, No. 2
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# THE RESISTANCE OF PEA VARIETIES TO FUSARIUM WILT

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ABOUT 200,000 acres of peas are grown each year in this country, and pea wilt causes serious losses, particularly in crops that are harvested green for marketing. The disease (Plate II, 2), caused by *Fusarium oxysporum* Fr. f. *pisi* (Linf.) Snyder & Hansen, is soil-borne and was first recorded by Linford (1928) in America; it has recently been recognized in Britain (Buxton and Storey, 1954). In common with many other soil-borne diseases, the chances of crop failure are increased when susceptible varieties are grown too often on the same land.

Pathogenic forms of *F. oxysporum* can survive in the soil for many years in the absence of their hosts, so that even a long break between susceptible crops will not eliminate the infestation, and it has become increasingly evident that Fusarium wilts are best combated by growing wilt-resistant varieties. The reactions of well-established pea varieties to wilt have been tested in the U.S.A. (Walker, 1931; Wade, Zaumeyer and Harter, 1938), New Zealand (Cruickshank, 1952) and Holland (Hubbeling, 1956), where resistant varieties have also been bred (Hagedorn, 1953; Yen and Cruickshank, 1957; Anon., 1957). So far, however, no one has attempted the breeding or selecting of peas for wilt-resistance in Britain. This paper describes field trials made to find whether any pea varieties widely grown in Britain resist infection by our native strains of the fungus.

## FIELD TESTS OF WILT-RESISTANCE

There are several problems inseparable from field tests of the resistance of plants to soil-borne pathogenic fungi. The two major difficulties with *F. oxysporum* f. *pisi* arise from the fact that it is a highly variable fungus, which occurs in a number of physiologic races, and is often unevenly distributed in the soil. Two precautions were taken to counteract these difficulties. The plots for testing for wilt-resistance were carefully chosen so that as many replicates as possible of each variety came within a patch of ground on which severe wilt had been previously recorded, and tests were made in two widely separated sites in case different physiologic races occur in different parts of the country.

The two sites used in 1958 were at Rayne, Essex and at Yaxley, Peterborough. Both had previously been cropped with peas that had suffered from severe wilt; in 1954 at Rayne and in 1957 at Yaxley. Ninety different pea varieties, chosen on the basis of popularity or possible introduction into this country, were grown at both centres. The peas were sown in single 6-foot rows, and each variety was replicated four times. The highly susceptible variety Onward was sown the length of each plot to indicate infection, and to use as a standard of susceptibility when disease records were made (Plate II, 3).

The plots were sown on March 25 at Rayne, and on April 2 at Yaxley. Wilt symptoms, which first appeared in some varieties during the last week of May, were recorded twice at each locality: on June 25 and July 10 at Rayne, and on July 2 and 12 at Yaxley. These dates were chosen on the basis of previous

experience (Fig. 1). Symptoms were classified on the following scale, and were finally tabulated from the independent observations of five recorders:

| *Scale of Wilt* | *Appearance of Plants* | *Reaction* | *Abbreviation* |
|---|---|---|---|
| 0 | Green and healthy | *Resistant* | R |
| 1 | Many leaves rolled, grey or yellow, frequently with orange-red vascular tract | *Moderately susceptible* | MS |
| 2 | All leaves grey or yellow, and rolled. Frequently with orange-red vascular tract, no pods formed | *Susceptible* | S |
| 3 | Plants completely withered, dead | *Very susceptible* | VS |

Table 1 shows the reactions of the ninety varieties used in the tests, together with indications of their main use. Forty-nine per cent of these varieties were resistant. Nineteen of the susceptible varieties contained a few plants that were wilt-resistant, presumably produced from seed genetically different from the bulk of the stock, which suggests the segregation of genes for resistance.

## TABLE 1

*Wilt Reactions of Pea Varieties Grown in Infested Soil at Rayne, Essex and Yaxley, Peterborough in 1958*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***Very Susceptible*** | | | | | | | | |
| Admiral Beatty | A | | Hurst's Stock VI | X* | | Peter Pan | AC* | |
| Alaska | C* | | Kelvedon Champion | A | | Pilot | AM | |
| American Wonder | AC | | Kelvedon Perfection | A | | Pioneer | A* | |
| Autocrat | A | | Kelvedon Spitfire | A | | Roi des Conserves | E* | |
| British Lion | CM | | Kelvedon Standby | A* | | Roi des Fins Verts | E | |
| Canning Queen | C | | Laxton's Progress | ACFM* | | Rondo | P | |
| Caractacus | E | | Laxton's Superb | ACFM | | Servo | P | |
| Feltham Advance | AM | | Little Marvel | AM** | | Tom Thumb | AC** | |
| Fertila | P* | | Mansholt's Pluk | P* | | Unica | P | |
| First and Best | A | | Miracle | A | | Union Jack | A* | |
| Gradus (early) | AM | | Onward | ACM | | Virtus | P | |
| Hundredfold | A** | | Pauli | P* | | William Massey (susceptible) | ACFM | |
| Hurst's Stock 47/1 | X** | | Partridge (susceptible) | S | | Witham Wonder (tall) | CFM* | |
| ***Susceptible*** | | | | | | | | |
| Kelvedon Lion | M** | | Lincoln | ACF** | | Thomas Laxton (ordinary) | ACFM | |
| ***Moderately Susceptible*** | | | | | | | | |
| Charles 1st | CF | | Gregory's Surprise | C | | Lincoln Small Blue | P | |
| Delicatesse | E* | | | | | | | |
| ***Resistant*** | | | | | | | | |
| Alderman | ACF | | Fin des Gourmets | E | | Senator | A | |
| Big Ben | P | | Freezer 37 | F | | Serpette Cent-pour-un | E | |
| Blue Prussian (W.R.) | X | | Giant Stride | A | | Shasta | CFM | |
| Canner No. 99 (white-seeded) | C | | Gradus (late) | CM | | Stratagem | A | |
| Canner No. 99 (green-seeded) | C | | Greenfeast (W.R.) | X | | Vares | P | |
| Canner's Perfection | CF | | Hurst's Stock V | X | | Victory Freezer | F | |
| Chanas | E | | Kelvedon Hurricane | A | | William Massey L.1 (W.R.) | X | |
| Chemin Long | E | | Kelvedon Monarch | ACFM | | William Massey L.2 (W.R.) | X | |
| Dark Skin Perfection | CF | | Kelvedon Viscount | A | | William Massey L.3 (W.R.) | X | |
| Daisy | A | | Lord Chancellor | AC | | William Massey L.4 (W.R.) | X | |
| Duplex | AF | | Morse's Market | A | | Witham Wonder (dwarf) | CFM | |
| Early Perfection | CF | | Onward (W.R.) | X | | Zelka | P | |
| Emigrant | P | | Partridge M.1 (W.R.) | X | | | | |
| English Wonder | AC | | Partridge M.2 (W.R.) | X | | | | |
| Express Freezer | F | | Perfected Freezer | F | | | | |
| | | | Progress No. 9 | AFM | | | | |
| | | | Rovar | P | | | | |

* = a few segregants seen
A = Amateur (gardens)
C = Canning
E = Exported for continental canning
F = Freezing
** = marked tendency to segregate
M = Market (sold in pod)
P = Packeting incl. canning as processed peas
S = Stock-feeding
X = Not in commercial use

In addition to the varieties used in these tests, the susceptibility to wilt of some other varieties and selections has been established from smaller trials done earlier and by isolations from commercial plantings. Observations made in 1957 at Yaxley are also included (Table 2).

## TABLE 2

### *Observations Previously Made on Wilt-resistance of Other Pea Varieties and Selections*

*Susceptible*

| | | |
|---|---|---|
| Clipper | ACFM | Feltham First AM |
| Combina (G) | C | Kelvedon Wonder ACFM |
| Dickson's Contentment | A | Lancashire Lad A |
| Double One (H) | CF | Last of All A* |
| Duplex† | AF | Late Queen A* |
| Dwarf Alaska | C | Laxton's Exquisite ACFM |
| Early Onward | ACM | Meteor ACFM |
| Fairbeard's Nonpareil | AC | Multifreezer 102 (U) F |
| Newburgh Victory | CM | |
| Selkirk (C) | F | |
| Tiny Tim | A | |
| Victoria | A | |
| Yates Early Crop (I) | CM | |
| 4127 (G) | C | |
| 7040 (G) | C | |

*Resistant*

| | | |
|---|---|---|
| A 46 (U) | C | Fraser (U) F |
| B 85 (U) | F | Harrison's Glory P |
| Balder (S) | AC | H 187–2 (U) C |
| Bonneville (I) | CM | Improved Early Perfection (U) C |
| Ceres (G) | C | Magnum Bonum A |
| Ceres Grun (G) | CF | Mira (G) C |
| Commonwealth | A | N 54 (U) F |
| Conserva VIII (H) | C | N 93 (U) C |
| Continuity | A | N 101 (U) C |
| Early Badger (I) | CM | Olympic (U) F |
| Early Greenpod (U) | C | Perfection 42(U) C |
| RN 31 (U) | C | |
| Salzmunder Edelperle (G) | C | |
| Salzmunder Frühe (G) | C | |
| Salzmunder Grüne (G) | CF | |
| Small Late Canner (U) | C | |
| Stamm 244 (G) | C | |
| Süsschnabel (G) | CM | |
| T 17 (I) | CM | |
| T 19 (I) | CM | |
| Wiwo (D) | C | |
| 320 (D) | C | |

Usage symbols are as in Table 1, and refer to use in country of source.

* = a few segregants seen.

† = shown as resistant in Table 1; here seed is from a different source.

*Country of origin of seed:*

(C) Canada (H) Holland (U) United States
(D) Denmark (I) India The remainder originated
(G) Germany (S) Sweden in Britain.

The source of these varieties, and those listed in Table 1, can be obtained from the authors.

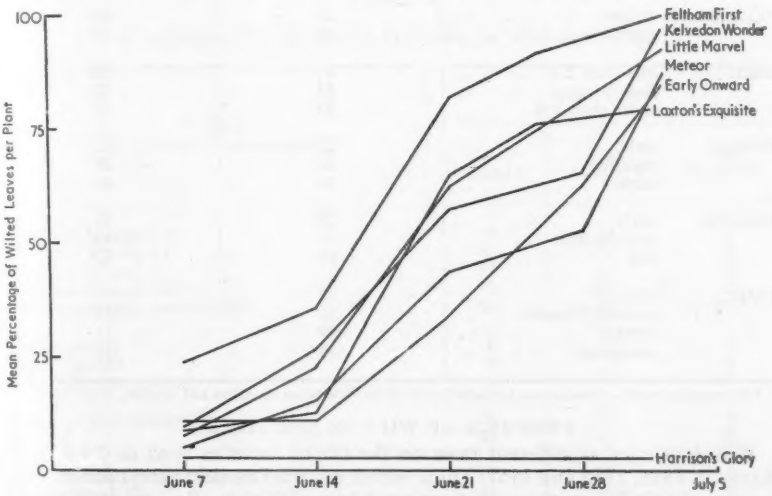


Fig. 1. Development of wilt in seven pea varieties grown in a wilt-infested field in Essex, 1956.

In the 1958 field tests (Table 1) the varieties reacted in the same way at Rayne as at Yaxley, except for Kelvedon Lion and Lincoln, both of which were moderately susceptible at Yaxley but very susceptible at Rayne. A few other varieties, notably Delicatesse and Thomas Laxton, showed rather milder

symptoms at Yaxley than at Rayne. The following varieties differed in our tests from results reported in Holland (Hubbeling, 1956):

| *Variety* | Caractacus | Daisy | Early Perfection | Senator | Victory Freezer |
|---|---|---|---|---|---|
| *Reaction in Holland* | R | VS | VS | VS | VS |
| *Reaction in Britain* | VS | R | R | R | R |

and from results published in New Zealand (Cruickshank, 1952):

| *Variety* | Early Perfection | Kelvedon Monarch | Kelvedon Standby | Laxton's Progress |
|---|---|---|---|---|
| *Reaction in New Zealand* | VS | VS | R | R |
| *Reaction in Britain* | R | R | VS | VS |

The population of physiologic races of the *Fusarium* is probably slightly different in each country, but most of our results agreed with those reported by Hubbeling and Cruickshank. As shown in Table 1, pea varieties bred in New Zealand and assessed there as wilt-resistant, were also resistant in Britain.

There was no correlation between wilt-resistance and several morphological characters, maturity or usage of the ninety pea varieties tested in 1958 (Table 3).

TABLE 3

*Percentage of Pea Varieties Resistant to Wilt in Relation to Morphological Differences, Maturity and Usage*

| Character | | Percentage of Varieties | No. of Varieties on which Percentages are Based |
|---|---|---|---|
| Seed shape: | round | 32 | 31 |
| | wrinkled (incl. indented) | 58 | 59 |
| *Cotyledons: | yellow | 10 | 10 |
| | green | 49 | 39 |
| Stem: | less than 2 ft | 44 | 16 |
| | 2–3 ft | 53 | 62 |
| | more than 3 ft | 33 | 12 |
| Foliage: | pale | 23 | 13 |
| | medium | 44 | 36 |
| | dark | 61 | 41 |
| Maturity: | early | 28 | 25 |
| | intermediate | 51 | 43 |
| | late | 68 | 22 |
| Usage: | amateur | 35 | 37 |
| | canning/freezing | 55 | 33 |
| | market | 29 | 17 |
| | packeting | 38 | 13 |

* Information on this character was available for 49 of the 90 varieties (Sneddon and Squibbs, *In. lit.* 1958).

## PROGRESS OF WILT IN THE FIELD

Wilt developed at different rates on the fifteen varieties used in the tests at Rayne in 1955, 1956 and 1957. Those which matured earlier, except for Meteor, developed wilt before those that matured late, although all were sown on the same day. Wilt occurred when the flowers were dying off and the pods were beginning to form. Fig. 1 shows examples of the rates of development of wilt in seven pea varieties.

Because the maturity of the plant rather than its actual age is correlated with the time of onset of wilt, it was necessary to make assessments in the field tests (Table 1) on at least two different dates.

### PHYSIOLOGIC RACES OF *F. oxysporum* IN THE TESTS

The possibility of differences arising because of certain physiologic races occurring in one locality but not in the other was tested by growing pea varieties, known to differentiate the races, in soil obtained from each site. Varieties Onward, susceptible to races 1, 2 and 3, Wilt-resistant Alaska, susceptible to races 2 and 3, but resistant to race 1, and New Era, susceptible to race 3 only, were used:

| *Reaction in soil from :* | *Rayne* | *Yaxley* |
|---|---|---|
| Onward .. .. .. .. .. | Wilt | Wilt |
| Wilt-resistant Alaska .. .. .. | Clean | Clean |
| New Era .. .. .. .. | Wilt | Clean |

The Yaxley soil apparently contained physiologic race 1 only, whereas the Rayne soil contained a race or races that wilted New Era and Onward, but not Wilt-resistant Alaska. Neither soil contained race 2, which has been found only rarely in this country (Buxton, 1955).

### TESTS OF WILT-RESISTANCE IN THE GLASSHOUSE

In an attempt to obtain a quicker test for wilt-resistance, extensive trials were made in a glasshouse at the N.I.A.B., Cambridge. Three different methods of testing were used:

1. Two-inch high seedlings were transplanted from seedling-boxes into pots of sterile compost after their roots had been dipped in spore suspensions of the *Fusarium*.
2. Spore suspensions were poured on the surface of the compost in pots containing seedlings, without transplanting.
3. Peas were grown from seed in pots of soil obtained from wilt-sick fields.

TABLE 4

*Glasshouse Testing of Pea Varieties for Wilt Resistance*

| Variety (* *ex* D.S.I.R., New Zealand.) | Wilt per cent | | |
|---|---|---|---|
| | *Test Method* 1 | *Test Method* 2 | *Test Method* 3 |
| *William Massey L1 .. .. .. .. | 79 | 28 | 0 |
| *William Massey L2 .. .. .. .. | 90 | 39 | 0 |
| *William Massey L3 .. .. .. .. | 77 | 10 | 0 |
| *William Massey L4 .. .. .. .. | 78 | 50 | 0 |
| *William Massey (susceptible) .. .. .. | 89 | 48 | 78 |
| *Partridge M1 .. .. .. .. .. | 0 | 0 | 0 |
| *Partridge M2 .. .. .. .. .. | 0 | 2 | 0 |
| *Partridge (susceptible) .. .. .. .. | 0 | 0 | 97 |
| *Onward (wilt-resistant) .. .. .. .. | 71 | 28 | 0 |
| Onward .. .. .. .. .. .. | 83 | 43 | 56 |
| *Blue Prussian (wilt-resistant) .. .. .. | 97 | 27 | 0 |
| Lincoln Small Blue .. .. .. .. .. | 58 | 16 | 0 |
| Rondo .. .. .. .. .. .. | 76 | 36 | 31 |
| *Greenfeast (wilt-resistant) .. .. .. | 87 | 25 | 0 |
| *Lincoln (wilt-resistant) .. .. .. .. | 83 | 22 | 0 |
| Lincoln .. .. .. .. .. .. | 64 | 23 | 34 |
| Harrison's Glory .. .. .. .. .. | 0 | 5 | 0 |

The interval between inoculation and recording was 28 days for method 1, 47 for method 2 and 44 for method 3. Differences in symptoms depended on which of the three methods of inoculation was used (Table 4).

Comparing the results in Table 4 with those shown in Table 1 shows that the use of sterile compost (methods 1 and 2) is unreliable. Nevertheless, these severe methods of testing failed to cause wilt in Partridge M.1, M.2, Partridge (susceptible) and Harrison's Glory. The failure no doubt results from using single-spore inoculum of a single race of the fungus in the pot tests, whereas the soil at Rayne may contain other races. Method 2, while still producing symptoms in the resistant Massey lines, appeared to be less severe than method 1. Only method 3, involving growing peas in soil from wilt-sick fields, gave a pattern of wilt-resistance resembling that in the field. This being so, little reliability can be placed on tests for field wilt-resistance that involve artificial inoculation techniques. However, the severe methods of adding inoculum to sterile compost might well be used in searching for genes for resistance for the purposes of breeding.

## DISCUSSION

Our results provide a basis from which stocks of wilt-resistant peas can be raised in Britain. This can be done either by selecting segregating plants from primarily susceptible stocks, or by breeding new lines from crosses between resistant and susceptible varieties. The former would yield lines that should remain fairly stable, for heterozygous progeny are not commonly produced in peas, which are self-fertilizing. Crosses between the popular but wilt-susceptible varieties and the less well-known resistant ones should be made in an attempt to produce high-yielding varieties of suitable quality that can be safely grown on land infested with the wilt fungus.

Our tests show that very few differences in wilt-susceptibility occur between two different pea-growing areas in this country, and between Britain and other countries. Such anomalies as do arise are probably caused by the uneven distribution of physiologic races of the *Fusarium*. It seems, therefore, that there would be a reasonable chance of a pea variety bred for resistance and tested in one part of the country, being equally resistant in another. However, it is possible that new varieties bred for resistance may eventually wilt. This could be caused either by segregation into resistant and susceptible lines or, equally likely, by the appearance of new physiologic races of the fungus.

## SUMMARY

In experiments on infested land at Rayne, Essex and Yaxley, Peterborough, 44 out of 90 pea varieties were resistant to wilt, caused by *Fusarium oxysporum* f. *pisi*. Including previous observations on other varieties, 77 out of 146 are known to be resistant in Britain. Most of the popular commercial varieties are wilt-susceptible and there is no correlation between morphological characters, maturity or particular commercial use, and reaction to wilt. Physiologic races 1 and 3, but not 2, were prevalent in the experimental fields. Testing for wilt-resistance by artificial inoculation methods in a glasshouse gave inaccurate forecasts of performance in the field, unless soil from infested fields was used. Further progress in combating pea wilt can best be made by breeding resistance into the susceptible commercially popular varieties; resistance data given may provide a basis for this work.

We wish to thank Mr. E. Sexton, Old Hall, Rayne, Essex, for kindly making land available for testing purposes; also the Instituut voor Rassenonderzoek van Landbouwgewassen, Wageningen, Holland, and Mr. L. J. Beaven, of Hurst & Son Ltd., Wholesale Seedsmen, London, for providing some of the seed, and for assistance in the experiments.

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# CONTROL OF THE GOOSEBERRY RED SPIDER MITE ON GOOSEBERRY

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STUDIES carried out on *Bryobia praetiosa* Koch in Switzerland (Mathys, 1954) and Austria (Böhm, 1954) established that there are several races with distinct host preferences and life cycles. Since then Meltzer, (1955) and Van Eyndhoven (1955 and 1956) give characters differentiating some forms, including that found on gooseberry, and consider them to be distinct species. Mathys (1954) and Böhm (1954) found that this form has only one generation per year, as Massee (1957) also states. In addition Mathys and Böhm conclude that in their respective countries eggs, the first of which are laid about mid May, overwinter and hatch in March and early April. An experiment on the control of this mite on gooseberries carried out at a market garden in Durham indicates that this species has approximately the same life cycle in the North of England. Eggs hatch about bud-burst, and, in 1957, after a mild winter, emergence began in the first week of March. By June 26 no mites could be found on the bushes.

The experiment comparing various control measures was laid out as a randomized block with three replicates and five treatments. Each plot consisted of two rows of four bushes. The treatments, which were applied at high volume, are shown in the Table. The DNC petroleum spray was applied on March 5, while the others were applied on April 16. Assessment was made by counting the number of mites on a ten-leaf sample from each of four bushes per plot, counts being done only under warm sunny conditions, as the mites leave the foliage during dull weather.

The DNC petroleum wash gave the best control even though applied rather late when the eggs were beginning to hatch. It was, however, equally effective against the young mites. Bushes so treated remained virtually free from the pest throughout the season and were outstanding in appearance, the leaves being

*Mean Number of Mites and Percentage Reduction by Treatment*

| Treatment | Mean Number of Mites per 40 Leaves per Plot | | | | Percentage Reduction |
|---|---|---|---|---|---|
| | *April 16* | *May 1* | *May 22* | *May 31* | |
| Control .. .. .. | 263 | 197 | 272 | 210 | — |
| DNC Petroleum (5 per cent Petroleum) .. .. .. | 4 | 1 | 1 | 5 | 99 |
| Tepp (0·01 per cent) .. | 181† | 41 | 51 | 57 | 78 |
| Parathion (0·01 per cent) .. | 199† | 16 | 14 | 30 | 91 |
| Schradan (0·027 per cent) .. | 210† | 35 | 20 | 8 | 91 |
| S.E. .. .. .. .. | 22 | 6 | 16 | 17 | — |
| Significant difference (p = 0·05) .. .. .. | 70 | 19 | 51 | 56 | — |

† Pretreatment counts.

larger and a darker, richer green. The other treatments were significantly better than the control, with no significant differences between treatments. During the interval between hatching and application of the spring sprays, considerable leaf damage had occurred. No appreciable difference was seen between these treated bushes and the controls until mid May, by which time there was even more mottling on the leaves of the controls, and more vigorous wood production was apparent on the treated plots.

Throughout the experiment cylindrical traps coated with "stictite" were placed vertically among the bushes. These were examined periodically to determine if the mites were dispersed by air movements. Mites were found on the traps only on June 26 clustered round the bottom margin of the "stictite", in a position suggesting they had crawled up the wooden post supporting the trap. On one trap, 382 mites were found, and 241 on the other. It appears that mites, towards the end of their life cycle, leave their original host bush, and that eggs may be laid on new bushes before death. The experiment confirmed that these mites move very little from bush to bush during April and May, since a small mite population developed on DNC treated bushes only where such a bush touched an infested one.

## SUMMARY

Excellent control of *Bryobia praetiosa* on gooseberry for the entire season may be obtained with a DNC petroleum wash. Spring sprays give adequate control, but to give maximum protection they should be applied as early as possible after the winter eggs have hatched.

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# INSECTICIDAL CONTROL OF WHEAT BULB FLY LARVAE

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CEREAL seed dressings intended for wireworm control do not always prevent serious damage by wheat bulb fly, *Leptohylemyia coarctata* Fall., when used at the conventional rate of 2 oz. per bushel of seed (equivalent to 0·08–0·04 per cent active ingredient to weight of seed) (Gough, 1953). Work was started to see if a better method of applying insecticide could be devised. The following materials and methods were tested during the period 1953–58:

SEED TREATMENTS. *gamma*–BHC and dieldrin, formulated with talc, were used as dry dusts to dress the seed in the usual manner, but at higher rates than normal. In field trials an aqueous solution of methyl cellulose was used as a sticker for dieldrin, aldrin and heptachlor (heptachloro–4, 7–methano tetrahydroindene).

COMBINE-DRILLING WITH THE SEED. In a preliminary experiment *gamma*–BHC, dieldrin and demeton were formulated with gypsum dust. For field tests dieldrin and aldrin were formulated with an inert siliceous filter to give a fine dust (mean particle size 9$\mu$). A granular formulation of dieldrin consisted of the insecticide coated on ¼-inch mesh brick chips.

BROADCAST TREATMENTS. For these, the siliceous earth formulation of dieldrin was broadcast along the rows by hand.

SPRAYS AND DRENCHES. In a small-scale trial, parathion and demeton were watered directly on to the plants, or applied with a small paint spray. In other trials, parathion, thimet (diethyl ethylthiomethyl dithiophosphate) and dipterex (dimethyl trichlorohydroxyethyl phosphonate) were applied with a spray boom carried by hand. The wetter used for dipterex, and for parathion in tables 1b and 2, was agral LN, consisting of ethylene oxide condensates with substituted phenols or fatty alcohols. Atlox 3335 was used in subsequent experiments. This is alkyl aryl sulphonate blended with polyoxyethylene sorbitan esters of mixed fatty and resin acids.

Experimental procedures varied. Initially seed dressings and "combine drill" treatments were tested in seed boxes artificially infested with fly eggs. The "combine drill" treatments were simulated by placement of the insecticide either in the trench containing the seeds ("seed drill") or in a similar trench containing the eggs ("egg drill"), the trenches then being filled in. Sprays and drenches were tested on 1-yd square microplots of wheat (Squarehead's Master). Field trials in 1954–57 were done on up to six replicates of plots varying in size from 9 to about 30 sq. yd on Rothamsted Farm, and were sown with Cappelle Desprez at 2 bushels per acre. The 1957–58 trial was at Newborough, near Peterborough on a fen soil. It consisted of four replicates of 170 sq. yd plots sown with Cappelle Desprez at 3 bushels per acre. For all field experiments the wheat was treated with an organo-mercurial fungicide.

All the results obtained with seed treatments are first described, followed by those with soil treatments, and finally those with spray treatments. The relative merits of these methods are considered in the discussion.

## SEED TREATMENTS

In the experiment summarized in Table 1a, dry seed dressings of dieldrin and *gamma*–BHC were applied at the maximum rate consistent with adherence to the seed (dieldrin) or absence of serious phytotoxic effects (*gamma*–BHC). Although dieldrin was applied at about twice the rate of *gamma*–BHC both treatments gave similar results, reducing the number of damaged tillers by half compared with untreated plants. There were slight phytotoxic effects with *gamma*–BHC.

TABLE 1

*Rothamsted Experiments, 1953–54*

| (a) Seed Box Experiments 1953–54 | | (b) Organo-phosphorus Liquids 1954 | |
|---|---|---|---|
| *Treatment* | *Mean no. Damaged Tillers* | *Treatment* | *Live Larvae (Square Root of No. per Sample)* |
| 2 per cent *gamma*–BHC dust in "seed drill" (9·9 lb *gamma*–BHC per acre). | 1·2** | 0·25 per cent Parathion spray. | 0·85** |
| 2 per cent *gamma*–BHC dust in "egg drill" (9·9 lb *gamma*–BHC per acre). | 0·8** | 0·05 per cent Parathion spray. | 0·93** |
| 2 per cent dieldrin dust in "seed drill"† .. | 6·6** | 0·01 per cent Parathion spray. | 1·62** |
| 2 per cent dieldrin dust in "egg drill"† .. | 4·8** | 0·25 per cent Parathion drench. | 0·00** |
| 2 per cent demeton dust in "seed drill"† .. | 2·4** | 0·05 per cent Parathion drench. | 0·00** |
| 2 per cent demeton dust in "egg drill"† .. | 0·2** | 0·01 per cent Parathion drench. | 0·99** |
| 70 per cent *gamma*–BHC seed dressing (0·28 per cent *gamma*–BHC to weight of seed). | 7·8** | 0·25 per cent Demeton drench. | 0·25** |
| 70 per cent dieldrin seed dressing .. (0·7 per cent dieldrin to weight of seed). | 7·0** | 0·05 per cent Demeton drench. | 0·25** |
| | | 0·01 per cent Demeton drench. | 1·85** |
| Gypsum dust in "seed drill"† .. .. | 18·6 | Untreated .. .. | 3·02 |
| Gypsum dust in "egg drill"† .. .. | 19·4 | 0·25 per cent "Agral LN" spray. | 2·30 |
| Untreated .. .. .. .. .. | 17·0 | 0·25 per cent "Agral LN" drench. | 2·50 |
| S.E. of difference between means | ± 1·8 | S.E. of difference between means | ±0·38 |

† 13·2 lb insecticide (or gypsum) per acre.

* Significantly different from untreated at p = 0·05; **ditto at p = 0·01 (The same convention is employed in Tables 2, 3, 4 and 5).

Dieldrin was then tested on a field scale, being applied at 2·25 per cent of the weight of the seed using technical dieldrin (97 per cent) and methyl cellulose as a sticker (Table 2). Phytotoxic effects were caused by the use of acetone as a solvent for applying dieldrin to the seed, and on April 5, this treatment had 37 per cent fewer shoots than the untreated plots. By May 5, the plants had recovered and these had less than a quarter as many damaged shoots as on the untreated plots.

The method described by Bardner (1958) was used to dress seeds for the 1957–58 trial at Newborough (Table 5). Seeds were treated with technical aldrin (95·7 per cent), dieldrin (100 per cent) or heptachlor (72 per cent heptachlor, 28 per cent related compounds) at 1 per cent and 0·15 per cent of seed weight. There were no phytotoxic effects and all seed treatments gave good control. By late April, 62·4 per cent of shoots on the untreated plots were damaged, compared with 16·5–33·0 per cent on plots treated with seed dressings. At harvest, yields were over twice as great from seed dressing plots than from untreated plots. The high rates were slightly superior to the low rates, and heptachlor seemed slightly better than aldrin or dieldrin.

These seed dressings were included in a trial on a clay soil at Southwick, Northants, together with a 40 per cent *gamma*–BHC dressing at 2 oz per bushel

(*gamma*–BHC 0·08 per cent of seed weight). *gamma*–BHC was inferior to these dressings. On May 1, the numbers of living larvae (square root transformation of numbers per sample) were: untreated 2·92; *gamma*–BHC 2·15, mean of low rate seed dressings 0·82; mean of high rates 0·17.

TABLE 2

*Rothamsted Experiment, 1954–55*

| Treatment (*Seed Sown 21.12.54*) | Per cent Damaged Shoots | | Yield (*cwt per acre*) |
|---|---|---|---|
| | *5.4.55* | *3.5.55* | |
| 4 per cent dieldrin dust combine drilled (5 lb dieldrin per acre) .. .. .. | 30·1** | 2·2** | 53·7** |
| Dieldrin seed dressing (2·25 per cent dieldrin to weight of seed) .. .. | 37·8** | 2·0** | 47·2* |
| Parathion sprayed 11.2.55 (0·05 per cent parathion + 0·2 per cent agral LN, at 100 gal/acre) .. .. .. .. | 46·8** | 5·3** | 47·9** |
| Parathion as above sprayed 7.4.55.. .. | — | 11·1 | 38·7 |
| No insecticide .. .. .. .. | 69·1 | 13·9 | 41·0 |
| S.E. of difference between untreated and any treatment .. .. .. .. | ± 7·9 | ±1·84 | ±2·30 |
| S.E. of difference between any two treatments .. .. .. .. .. | ± 9·7 | ±2·12 | ± 2·7 |

SOIL TREATMENTS

Table 1 shows that demeton and *gamma*–BHC appeared to be somewhat better than dieldrin for "combine drill" application at the rather high rates used. Demeton dust was not tested further, because of its hazardous nature. *gamma*–BHC dust was also rejected because of the possibility of tainting root

TABLE 3

*Rothamsted Experiment, 1955–56*

| Treatment (*Seed Sown 1.11.55*) | Per cent Damaged Shoots | | Live Larvae (*Square Root of No. per Sample*) | | Yield (*cwt per acre*) |
|---|---|---|---|---|---|
| | *21.3.56* | *27.4.56* | *21.3.56* | *27.4.56* | |
| 4 per cent dieldrin dust combine drilled (5 lb dieldrin per acre) | 7·7* | 1·6** | 2·80* | 0·60** | 45·9 |
| 4 per cent dieldrin dust broadcast (5 lb dieldrin per acre) .. | 16·4 | 2·4** | 4·18 | 0·60** | 52·3* |
| Parathion sprayed 2.3.56 (0·1 per cent parathion + 0·4 per cent Atlox 3335 at 100 gal per acre) .. .. .. .. | 17·4 | 7·7** | 3·84* | 2·73* | 45·7 |
| Parathion as above sprayed 12.4.56 .. .. .. | — | 4·8** | — | 1·00** | 48·5 |
| No insecticide .. .. .. | 24·4 | 14·1 | 4·85 | 3·70 | 46·2 |
| S.E. of difference between means of untreated and any treatment .. .. .. .. | ± 3·9 | ± 1·5 | ±0·42 | ±0·36 | ± 1·8 |
| S.E. of difference between means of treatments .. .. .. | ± 4·8 | ± 1·8 | ±0·51 | ±0·42 | ± 2·1 |

crops grown after wheat. Dieldrin was combine drilled on a field scale in 1954 (Table 2), the rate of application being reduced to 5 lb actual dieldrin per acre. This was comparable with the rate of 2–6 lb per acre of dieldrin or aldrin used to control a variety of soil pests (Compton and McCauley, 1951; King and Forbes, 1954; Stitt, 1951; Rawlins and Newhall, 1950; Wagn, 1953). The treatment proved very successful, reducing the numbers of damaged shoots by 70 per cent in early May, and giving a 30 per cent increase in yield compared with untreated plots. In the following season (Table 3) this treatment gave good results, equalled only by a similar quantity and formulation of dieldrin broadcast over the plots just before the larvae hatched out.

These two treatments were again compared in 1956–57 (Table 4a). Dieldrin dust was also broadcast in late December. Other treatments were dusts of aldrin and dieldrin, and dieldrin granules, all combine drilled at 2 lb insecticide per acre. Scarcity of wheat bulb fly made the assessment of results difficult. The best treatment was the December broadcast of dieldrin, the worst the combine-drilling of dieldrin granules.

TABLE 4

*Rothamsted Experiments, 1956–57*

| (a) Soil Insecticides (*Seed Sown 5.11.56*) | | (b) Organophosphorus Sprays (All Applied as 0·1 per cent Spray, Measurements by Volume) | |
|---|---|---|---|
| *Treatment* | *Per cent Damaged Shoots 14.4.57* | *Treatment* | *Live Larvae (Square Root of No. per Sample)* |
| 4 per cent dieldrin dust (5 lb dieldrin per acre) .. .. | 2·4** | Thimet, dilute proprietary emulsion sprayed 15.3.57 .. | 3·3 |
| 1·5 per cent dieldrin dust (2 lb dieldrin per acre) .. .. | 3·2** | Parathion + 0·18 per cent Xylene + 0·4 per cent Atlox 3335 sprayed 27.2.57 .. .. | 3·0* |
| 1·5 per cent aldrin dust (2 lb aldrin per acre) .. .. | 2·8** | Parathion as above sprayed 15.3.57 .. .. .. .. | 3·4 |
| 1·2 per cent dieldrin granules (2 lb dieldrin per acre) .. | 3·4** | Parathion + 0·4 per cent Atlox 3335 sprayed 15.3.57 .. | 2·8* |
| 4 per cent dieldrin dust broadcast 18.12.56 (5 lb dieldrin per acre) .. .. .. .. | 0·8** | Parathion + 0·26 per cent Xylene + 0·014 per cent Atlox sprayed 15.3.57 .. | 3·5 |
| 4 per cent dieldrin dust broadcast 16.2.57 (5 lb dieldrin per acre) .. .. .. .. | 2·4** | 0·1 per cent Parathion + 0·18 per cent Xylene + 0·014 per cent Atlox + 0·6 per cent methyl cellulose sprayed 15.3.57 .. .. .. | 2·5* |
| Untreated .. .. .. .. | 7·1 | Untreated .. .. .. | 4·0 |
| S.E. of difference between means | ± 1·3 | S.E. of difference between controls and treatments .. .. | ±0·46 |
| | | S.E. of difference between treatments .. .. .. .. | ±0·52 |

In 1957–58, combine drillings of aldrin and dieldrin at 1·5 lb per acre were tried at Newborough (Table 5). The two materials performed similarly. There was a substantial control of wheat bulb fly damage but this was inferior to that achieved by seed dressings in the same trial.

### SPRAYS AND SOIL DRENCHES

In a preliminary experiment (Table 1b) sprays of parathion and demeton at 100 gal per acre were compared with soil drenches of the same materials watered at 500 gal per acre. Parathion was formulated with an equal volume of agral LN, demeton with an equal volume of benzoyl–*p*–oxydiphenyl polyglycol ether. Plants were sprayed on April 1, 1954 and sampled one week later. All larvae were killed by a 0·05 per cent parathion emulsion soil drench. The same concentration sprayed killed 87 per cent of larvae. The spray treatment was compared with other methods of application on a field scale in the following season (Table 2). It was considered that spray treatments might be of practical use early in the season, when larvae were hatching, and later, just before larvae migrate to fresh shoots. At this time shoots originally attacked by the larvae die, and the attack is noticeable to the farmer. Sprays were applied at both these times. The early spraying halved the numbers of damaged shoots compared with the untreated plots, but the late spraying was not satisfactory. When the parathion concentration was doubled, and a different wetter used, a significant degree of control was achieved with both early and late sprays, though soil treatments of dieldrin appeared to be superior to sprays (Table 3).

In 1957 (Table 4b) an attempt was made to compare different dates of spraying. Larval populations were small, making the results difficult to assess. The most successful formulations were parathion with a high proportion of wetter (as used in 1956), and also when made up with a sticker for adhesion to the foliage. A spray applied at the beginning, instead of the middle of the hatching period also had some effect. A spray containing thimet was not effective. A small trial in 1956, showed that dipterex was, if anything, less effective than parathion when both were applied as 0·1 per cent sprays at 100 gal per acre. The numbers of larvae per sample (square root transformation) fifteen days after spraying were parathion, 1·61; dipterex, 2·64; unsprayed, 4·09.

TABLE 5

*Newborough Experiment, 1957–58*

| Treatment (*Seed Sown 8.11.57*) | Per cent Damaged Shoots | | Live Larvae (*Square Root of No. per Sample*) | | Yield (*cwt per acre*) |
|---|---|---|---|---|---|
| | *18.3.58* | *21.4.58* | *18.3.58* | *21.4.58* | |
| Aldrin seed dressing 0·15 per cent by weight of seed .. | 41·3** | 23·4** | 4·27** | 1·75** | 25·2** |
| Aldrin seed dressing 1 per cent by weight of seed .. .. | 39·6** | 20·1** | 2·65** | 1·22** | 25·4** |
| Dieldrin seed dressing 0·15 per cent by weight of seed .. | 43·4** | 33·0** | 6·00** | 3·34* | 23·5** |
| Dieldrin seed dressing 1 per cent by weight of seed .. .. | 37·1** | 16·5** | 4·85** | 1·63** | 25·7** |
| Heptachlor seed dressing 0·15 per cent by weight of seed .. | 36·1** | 22·2** | 4·30** | 2·16** | 25·6** |
| Heptachlor seed dressing 1 per cent by weight of seed .. | 31·9** | 17·7** | 2·28** | 1·14** | 27·6** |
| Aldrin dust combine drilled (1·5 lb aldrin per acre) .. | 53·9 | 39·4** | 6·84 | 3·45* | 19·7** |
| Dieldrin dust combine drilled (1·5 lb dieldrin per acre) .. | 41·8** | 40·3** | 6·25** | 3·89 | 17·0** |
| Untreated .. .. .. | 63·6 | 62·4 | 8·11 | 4·82 | 11·5 |
| S.E. of difference between means | ± 5·6 | ± 5·9 | ±0·63 | ±0·66 | ± 1·9 |

## DISCUSSION AND SUMMARY

Insecticides applied at the time of sowing as seed dressings or combine drill treatments may prove unnecessary, particularly on early sown wheat, which usually has time to tiller before attack. These methods are effective mainly on late-sown or backward crops. Methods of applying insecticides during the period of larval attack would be useful. Sprays are an obvious choice, but were inferior to seed dressings or combine drill treatments in these experiments. Young wheat plants have only a small amount of foliage for spray to adhere to, and also have a high contact angle with water droplets (Fogg, 1947), making them difficult to wet. The addition of large quantities of wetter, or a sticker to the spray seemed to be advantageous. Parathion at 0·05–0·1 per cent was the cheapest and most effective spray tested. Sprays might be of some value in saving a crop that would otherwise have to be re-drilled.

Broadcast treatments can be applied just before the start of larval attack. Results using about 5 lb actual dieldrin per acre were promising.

Of the treatments applied at the time of sowing, 4 per cent dieldrin dust combine-drilled with the seed to give 5 lb actual dieldrin per acre was the treatment most extensively tested and gave good results. Recent experiments by N.A.A.S. workers (unpublished) show that 2 lb aldrin per acre is satisfactory. Aldrinated fertilizer can also be used for combine-drilling.

Soil insecticides are usually most effective as a seed dressing, and this is also the simplest method of protection. In the Newborough trial, aldrin and dieldrin combine-drilled at 1·5 lb insecticide per acre gave reasonable control, but were inferior to seed dressings at 0·15 and 1 per cent of seed weight (0·29 and 1·92 lb insecticide per acre). The high rate of seed dressing was only moderately better than the lower rate. Heptachlor was slightly better than aldrin or dieldrin. From another trial it appears that dressings at these rates were better than a dressing of *gamma*–BHC at 0·08 per cent of seed weight and they were also the most satisfactory method of control tested. Heptachlor and dieldrin were the best of twenty-seven insecticides tested as seed dressings against wheat bulb fly. (Bardner, 1958.)

My thanks are due to Messrs. F. Maskell and R. Gair of the N.A.A.S. who collaborated in trials outside Rothamsted, to Mr. J. H. A. Dunwoody for statistical analysis, Mr. M. J. Way for advice and suggestions and to Mr. P. Etheridge who assisted in these experiments.

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# ALDRIN CONTROLLING SLUG AND WIREWORM DAMAGE TO POTATOES

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A PRELIMINARY examination of the results of an experiment done in 1954 seemed to indicate that the effect of aldrin in preventing slug damage was not significant, though the effect on wireworms was considerable. Recently, however, Dr. K. Mellanby has re-examined the results, and has suggested that they should be published, as the effects on slugs appear to be more important than was previously realized.

A site in the Highfield ley arable experiment at Rothamsted was used. A rectangular block was divided into twelve plots 83 × 27 feet, with narrow paths between. Four plots were used as controls, and the remainder received 1¼ per cent aldrin dust at two levels of application, the dust being applied just before planting the potatoes. Four plots received 240 lb of dust per acre and the remaining four 480 lb. Controls and treated plots were randomized and replicated. The variety of potatoes used was Majestic, and the haulms were sprayed with 5 per cent sulphuric acid early in October shortly before lifting.

The tubers were harvested using an elevator digger and, as the potatoes were lifted, random samples of approximately 28 lb were collected in sacks and taken to the laboratory. On opening the sacks the first fifty tubers were removed, and this sub-sample was used to assess slug and wireworm damage.

The tubers were scrubbed free from soil in cold water and examined individually. Damage was first assessed on an arbitrary scale: undamaged, slight, moderate, and heavy. However, as only five of the 600 tubers examined were heavily damaged, it was decided to divide the potatoes into two groups only, undamaged, and damaged. Some difficulty was experienced in classifying the type of damage. Where there was a definite "tunnel" this was attributed to wireworms, whereas irregular depressions or cavities were attributed to slugs. Some errors of diagnosis were undoubtedly made, but they were probably few. The totals in the table are for the four plots given each treatment added together, as they gave consistent results, differences within treatments between plots not being significant.

*Effects of Treatments on Damage to Tubers*

| No. of Tubers | Untreated Control | Treated with 1¼ per cent Aldrin Dust | |
|---|---|---|---|
| | | *240 lb per acre* | *480 lb per acre* |
| Total .. .. .. .. | 200 | 200 | 200 |
| Undamaged by slugs .. .. | 151 | 171 | 188 |
| Damaged by slugs .. .. | 49 | 29 | 12 |
| Undamaged by wireworms .. | 116 | 160 | 183 |
| Damaged by wireworms .. | 84 | 40 | 17 |

The difference in the rate of damage both by slugs and wireworms was statistically significant at the 5 per cent point in the three groups.

In this particular experiment both slug and wireworm damage were slight. The effects of a heavier attack might have been different. Maskell (1958) has shown that different results may be obtained with aldrin, and other insecticides, in different years.

The figures for wireworm control agree with those of Raw and Potter (1958), who found that 3·56 lb of technical aldrin per acre (an amount intermediate between the two doses used here), reduced the wireworm population very effectively.

I thank Dr. R. M. Dobson and Mr. J. R. Lofty who shared in the work of sorting the potatoes.

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# LETTUCE RINGSPOT: A SOIL-BORNE VIRUS DISEASE

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IN June 1956 some lettuce plants of the variety "Cobham Green" were received from a grower in Norwich; the plants were in poor condition and showed a number of yellow spots on the lower leaves. Routine inoculations were made to White Burley tobacco and other test plants; in about ten days there developed local necrotic rings on the inoculated leaves of the tobacco plants, followed by a systemic disease of a very pronounced ringspot type (Plate I, 1 and 2).

In August of the same year, another batch of six lettuces grown locally were sent in for testing. These plants though in poor condition showed no evident virus symptoms, but inoculation to tobacco plants produced the same ringspot disease as did the first batch of lettuce plants, all six plants being infected.

## HOST RANGE AND SYMPTOMATOLOGY OF THE LETTUCE RINGSPOT VIRUS (LRV)

*Gomphrena globosa.* Local lesions consisting of large red rings with necrotic centres; no systemic spread.

*Chenopodium amaranticolor.* Numerous very small necrotic spots on inoculated leaves; no systemic spread.

*Tetragonia expansa*, New Zealand spinach. Local lesions consist mostly of single necrotic rings, followed by a systemic necrotic disease. The leaves show numbers of necrotic rings and are badly distorted.

*Phaseolus vulgaris*, French or string bean. Local chlorotic lesions develop followed by a systemic mottle. Plant rapidly grows away from the symptoms.

*Cucumis sativus*, ridge cucumber. This type of cucumber plant shows a mosaic mottling which rapidly disappears. The hothouse variety of cucumber,

"Telegraph", however, reacts to the lettuce ringspot virus similarly to infection with tomato black ring virus (Smith, 1946) and develops pronounced enations on the undersides of the leaves.

*Nicotiana tabacum*, var. White Burley. A rather severe but characteristic tobacco ringspot disease developed (Plate I, 1 and 2).

*Nicotiana glutinosa*. Local lesions consisting of single necrotic rings develop on the inoculated leaves, followed by a ring-and-line pattern much less severe than on tobacco.

*Lycopersicon esculentum*, tomato var. "Kondine Red". In June, inoculated plants developed a reddish veinal necrosis which sometimes became a lethal stem necrosis (Plate I, 3). Infected plants rapidly grew away from the disease. In September, infected tomato plants behaved rather differently, there was no veinal necrosis but a rather necrotic systemic mottle of a ring-and-line pattern developed (Plate I, 4).

*Lactuca sativa*, L. It seems clear that some varieties of lettuce show no symptoms when infected with LRV, whilst others may develop some mosaic mottling and distortion. Seven varieties of lettuce were inoculated by rubbing with the ringspot virus, of these, four failed to become infected. These varieties were "Tom Thumb", "Imperial", "Webb's Wonderful" and "Bath Cos"; the three infected were "Cheshunt Early Giant", "Arctic King" and "All the Year Round".

## PROPERTIES OF THE VIRUS

*Dilution End-point*. This was found to be between $10^{-1}$ and $10^{-2}$ using tobacco as a source plant and *N. glutinosa* as a test plant.

*Thermal Inactivation Point*. The virus withstands 10 minutes between 50° and 60°C.

*Longevity in vitro*. This is 4–5 days at room temperature in extracted tobacco sap.

## TRANSMISSION

*Mechanical Transmission*. The virus is easily transmissible by rubbing with carborundum.

*Insect Vectors*. Negative results were obtained with both long and short feeding using the aphids *Myzus persicae* and an undetermined species from lettuce.

*Soil Transmission*. In experiments with naturally infected soil the experimental plants were grown in pots containing soil from which infected plants had been removed. Of eighteen lettuce seedlings grown under these conditions, one plant became infected; of thirty lettuce seedlings similarly grown three became infected; and of thirty-five tobacco seedlings, var. "White Burley", none became infected.

In experiments in which artificial infection of soil was attempted, virus-containing sap was mixed with the soil before planting the seedlings. Of forty lettuce and tobacco seedlings grown in this way, none became infected.

*Root Inoculations*. Out of twelve tomato plants, inoculated by bruising the roots in sap containing the lettuce ringspot virus, nine became infected.

## CROSS-IMMUNITY TESTS

*Tropaeolum Ringspot Virus*. In two experiments with this virus, which produces rather similar ringspot symptoms on tobacco, no protection resulted.

*Tomato Black Ring Virus* (TBRV). The similarity between various reactions of the two viruses suggested a relationship, and complete cross-protection was

obtained in eight tobacco plants infected with TBRV. This was made possible by the different type of ringspots formed on the leaves of tobacco by the two viruses.

## DISCUSSION

Although there are slight but definite symptom differences between the lettuce ringspot virus and the tomato black ring virus, notably on tomato and *C. amaranticolor*, the very peculiar symptoms on "Telegraph" cucumbers, the cross-protection tests, and the similar properties of the two, leave no doubt that they are strains of the same virus.

The results of the soil-transmission tests with lettuce ringspot virus bear out those of Cadman (1956) and Harrison (1957), who also found that transmission of soil-borne virus did not occur in artificially infected soil. Since, like LRV, TBRV easily enters the roots of tomatoes when mechanically inoculated, it is curious that all our soil-transmission tests carried out with this virus have been negative, even when the test plants were grown in naturally infected soil. Harrison (1958), however, has had positive soil-transmission with a strain of this virus. When the TBRV was first discovered (Smith, 1946), there seemed no doubt that some spread must have occurred in the various glasshouses where it was found. It is probable, however, that the spread took place when the plants were very young. The virus was first isolated from a single tomato fruit which also contained tobacco mosaic virus and potato virus X. The infected tomato plants subsequently received were all very young and this is to be expected since, after the initial disease, the plant grows away from all symptoms.

It is clear that much more work is needed on the conditions governing the transmission through the soil of these two viruses and as to whether some kind of soil-living vector is concerned. It will be interesting to make comparisons between TBRV, LRV, tobacco broken ringspot virus (Smith and Markham, 1944) and tomato ringspot virus as it occurs in the U.S.A. On a recent visit to the laboratory of Professor Frank Ross at Ithaca, one of us (KMS) was shown a tobacco plant "spontaneously" infected in the glasshouse with what was thought to be the American virus known as "tomato ringspot virus". The similarity of the symptoms on tobacco, and the mode of infection in the glasshouse, suggest very strongly that the English broken ringspot virus and the American tomato ringspot virus are the same or closely related, and that both are soil-transmitted.

## SUMMARY

An account is given of a soil-borne sap-transmissible virus occurring in lettuce plants; because of the characteristic symptoms produced on tobacco the name "lettuce ringspot virus" is suggested. Cross-protection tests and similarity of symptoms on certain hosts show it to be a strain of tomato black ring virus.

The photographs were taken by S. Frey.

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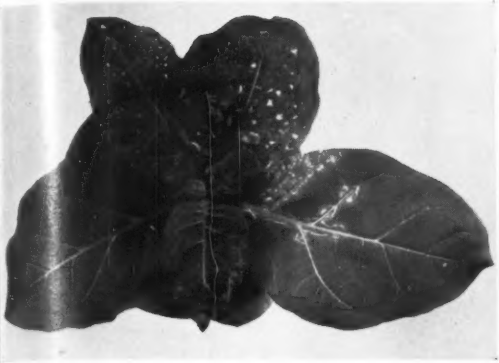
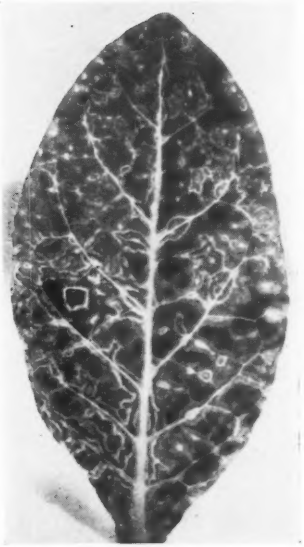
# LETTUCE RINGSPOT



1. *Above:* Tobacco plant, variety "Xanthi", inoculated with lettuce ringspot virus (LRV) showing a systemic disease of the ringspot type.



2. *Right:* Leaf of "White Burley" tobacco, showing the ringspot symptoms caused by LRV.

3. Tomato leaf infected with LRV in June, showing veinal necrosis.

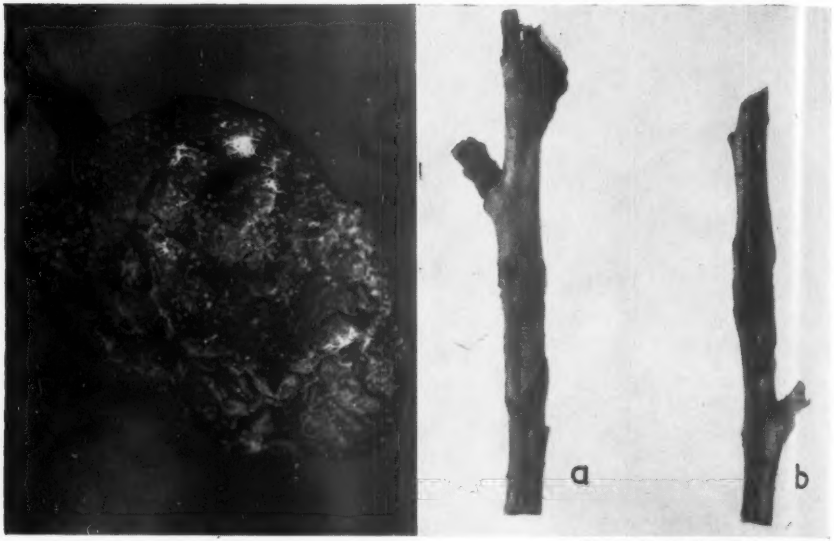
4. Tomato leaf infected with LRV in September, showing the faint ring-and-line pattern symptoms.

*Photos: A.R.C. Virus Research Unit, Cambridge*

PLATE I

## ORCHARD SOURCES OF INFECTION BY *GLOEOSPORIUM* SPP.

(see p. 71)




*Photos: Long Ashton Research Station*

1. *Left:* Saprophytic infection of *G. album* showing acervuli on old mummified Cox fruitlet. *Right:* Sporing leaf scar infections of *G. perennans*, a. initiated naturally by conidia from snag infections above; b. initiated by inoculation of freshly exposed leaf scar in October, 1957. Shoots photographed June 1958 after removal of foliage.

## RESISTANCE OF PEA VARIETIES TO FUSARIUM WILT

(see p. 39)

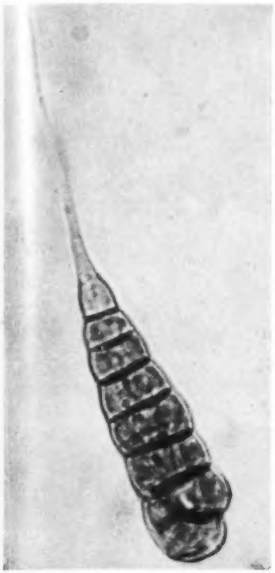
*Photos: Rothamsted Experimental Station*

2. Typical symptoms of wilt, variety "Kelvedon Standby".

3. Susceptibility of "Onward" (in front), contrasted with resistance of "Senator" (in rear).

PLATE II

## ALTERNARIA LEAF BLIGHT OF CARROTS (see p. 76)



1. Typical long-beaked spore (× 1,000).

2. Ragged appearance of inner leaf with blighted leaflets.

3. Field symptoms showing decay of outer leaves and survival of central tufts.

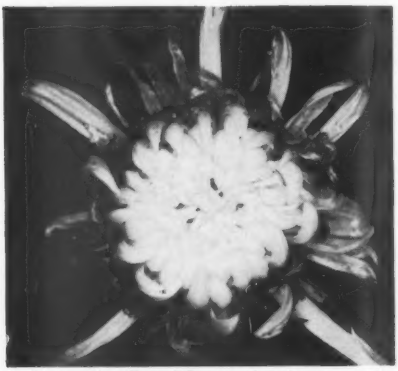
PLATE III

## GREY MOULD OF CHRYSANTHEMUM FLOWERS

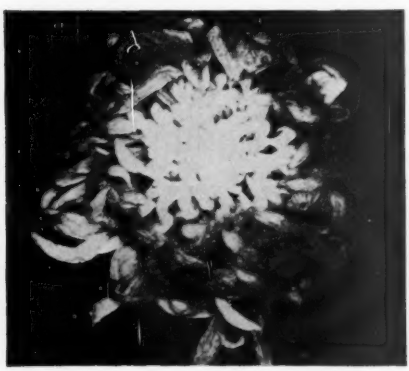
1. Healthy flower.

2. Florets affected with the diffuse spotting phase of grey mould.

3. Naturally affected flower, showing a few scattered, brown, diseased florets.



4. Naturally affected flower, showing a complete ring of diseased florets.



5. Naturally affected flower, showing development of the conidial stage of *Botrytis cinerea*.

*Photos: Ministry of Agriculture, Northern Ireland*

6. Affected flower showing a complete ring of diseased florets as the result of inoculation with conidia of *B. cinerea*.

PLATE IV

# GREY MOULD OF CHRYSANTHEMUM FLOWERS

*by* J. C. TAYLOR *and* A. E. MUSKETT

*Plant Pathology Division, Ministry of Agriculture, Northern Ireland*

GREY mould of chrysanthemum blooms occurs widely in unheated glasshouses. Normally, the first symptoms of the disease are the occurrence of elliptical lesions on a few florets in the flower head. These enlarge, giving the floret a water-soaked appearance and, finally, the conidial stage of *Botrytis cinerea* Fr. is produced, the conidia usually appearing first near the distal end of the floret. If the disease develops rapidly the blooms become water-soaked and discoloured so quickly that the elliptical lesions, typical of the early phase of attack, may escape notice.

In 1957 an unusually severe infection of flower buds of the Wallace family of chrysanthemums occurred in a nursery in Co. Down. The crop was grown outdoors until late September when it was protected by a structure, the roof of which was built of Dutch lights; side protection being given by polythene sheeting. Ample ventilation was provided during the day irrespective of weather conditions. To protect the plants from undue cold, a 3 kW heating unit and fan was fitted at one end of the structure which was 150-feet long, and this was set to operate whenever the temperature fell below 45°F. (7°C.). A fan was also fitted at the centre of the house to encourage air circulation and was operated from 5 p.m. to 8 a.m. each day.

In mid October the grower reported damage to the flower buds which he suspected had been caused by insect or smoke injury to the expanding florets. On examination, the first crown buds exhibited a diffuse spotting or flecking on those parts of the florets which were exposed (Plate IV, 2). Each spot involved a group of a few cells which showed a red pigmentation, particularly of the cell walls and, in the case of the larger spots, a slight depression of the surface was observed. The spotting was much more easily noticeable on Yellow Wallace than on pink May Wallace or White Wallace, although the spots were equally numerous on all three varieties. The affected buds, on opening, produced blooms with either a few scattered, brown, water-soaked florets (Plate IV, 3), or showing a complete ring of diseased florets (Plate IV, 4). Frequently, the original site of infection in a diseased floret was marked by a distinct elliptical lesion. More than 50 per cent of the affected blooms were unfit for market.

As only isolated aphids were found throughout the crop, and as most of the damaged buds would not have been open when fumigation was carried out with BHC, using smoke bombs, these possible causes were ruled out. No fungal mycelium was detected in the spots and fleckings in their early stages of development but it was abundant in the larger lesions and water-soaked florets, all of which readily developed conidia of *Botrytis* on incubation (Plate IV, 5). The widespread occurrence of the diffuse spotting of the opening blooms suggested that if *B. cinerea* was responsible then the plants must have been subjected to a continuous, heavy, aerial infection. Although the upper foliage was clean and healthy the fungus was abundant on the lower leaves of the plants, and was also observed growing on lettuce detritus adhering to some of the roof lights which had not been washed and cleaned before use. To obtain some measure of the spore load in the air of the structure, petri dishes containing 2 per cent malt agar were exposed on the floor of the house for five minutes at dusk, while others were exposed from 10 p.m. to 8 a.m. Both sets of dishes developed numerous colonies of *B. cinerea*.

Infection trials were carried out in an adjacent unheated glasshouse containing plants of the Wallace family which had been grown outdoors and

transferred to the house in late September. In this house there was almost a complete absence of the disease. Conidia from infected blooms and leaves were dusted on to partially expanded buds and opening blooms. Those which were half open and heavily dusted with spores at dusk on November 11 contracted infection and showed an advanced stage of disease by November 14 (Plate IV, 6). While most of the outer florets remained healthy, the inner expanded florets became water-soaked and brown and the innermost florets developed the diffuse spotting phase of the disease at their distal ends. Buds, dusted at the same time, also developed diffuse spotting of the unopened florets. Such infected buds, whether left on the plants or incubated in the laboratory, produced only occasional water-soaked and browned florets. Spotted florets plated out on malt agar usually showed an abundant development of *Botrytis* but, if first surface sterilized by gently wiping them with cotton wool saturated with ethyl alcohol, the development of *Botrytis* tended to be confined to those showing elliptical lesions or larger coalesced spots.

The spotting phase of grey mould of chrysanthemums bears resemblance to the non-aggressive phase of infection by *B. cinerea* on beans (Wilson, 1937), to water spot of tomato fruits (Ainsworth, Oyler and Read, 1938), to cyclamen petal spot (Tompkins and Hansen, 1948) and to flower blight of *Stephanotis floribunda* caused by *Botrytis elliptica* (Tompkins and Hansen, 1950). Owen and Ferrer (1957) found that inoculation of tomato fruits, under glass, with conidia of *B. cinerea* gave necrotic flecks with only 1 per cent of the fruits developing ghost spot. When fruit, on outside plots, was inoculated during the cool night period and left exposed to bright sunlight and high temperatures the next day, 57 per cent developed ghost spot. No fungus could be isolated from the diseased fruits although a stainable, fungus-like material was recorded as occurring in the necrotic spots. Ainsworth, Oyler and Read (1938) also failed to isolate a fungus from spotted tomato fruits and Wilson (1937), working with beans, records the presence of mycelium as sparse in non-aggressive infections but abundant in lesions caused by aggressive infection. Tompkins and Hansen (1950) consistently obtained *B. elliptica* from sterilized tissue fragments of naturally infected flower buds and open flowers of *Stephanotis floribunda*, but did not distinguish between tissue showing only spots or flecks and that showing lesions.

It is, therefore, concluded that all stages of the diseased condition of chrysanthemum flowers here recorded, from the diffuse spotting of the florets to the death of the great majority of the florets in any one bloom, are due to infection with *Botrytis cinerea*, the fungus responsible for grey mould. The further development of the disease from the spotting phase onwards would appear to be related to the stage of flower development and the environment. Reference has already been made to the prevalence of the disease in the structure and its relative absence in the adjacent unheated glasshouse. Although no strict comparison is possible between the conditions prevailing in the structure and the glasshouse, it is of interest to note the frequent development of *B. cinerea* recorded on lettuce detritus attached to the uncleaned Dutch lights, which formed the roof of the structure, and the induced circulation of air by night, which could effectively distribute the spores of the fungus.

SUMMARY

The occurrence of a severe flecking of the florets in chrysanthemums is reported from a Dutch-light structure in Northern Ireland. The causal organism was shown to be *Botrytis cinerea* Fr. and symptoms were reproduced by artificial inoculations.

Thanks are due to Mr. Robert McIlwaine for assistance with the photographs.

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# EYESPOT ON WHEAT IN LEY-ARABLE ROTATION EXPERIMENTS AT ROTHAMSTED, 1952–58

*by* G. A. SALT

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THE ley-arable experiments at Rothamsted provided an opportunity to compare the incidence of soil-borne diseases on winter wheat in an arable, with that in an alternate ley-arable rotation. The experiments, begun in the autumn of 1948, were planned to compare soil fertility and productivity under the different cropping systems, and are taking place in two fields with basically similar soil but with contrasting initial conditions. "Fosters" had been arable for at least 100 years, whereas "Highfield" had been parkland grass for even longer. Details of the experiment appear in the Rothamsted Report for 1948; the general cropping scheme can be summarized as follows:

| Rotation | Treatment Crops | | | Test Crop | | |
|---|---|---|---|---|---|---|
| | *1st year* | *2nd year* | *3rd year* | *4th year* | *5th year* | *6th year* |
| Arable .. | Hay | Potatoes | Barley or Oats | Wheat | Potatoes | Barley |
| Ley .. .. | Grass grazed by sheep | | | Wheat | Potatoes | Barley |
| Cut grass .. | Grass cut for drying | | | Wheat | Potatoes | Barley |
| Lucerne .. | Lucerne cut for hay | | | Wheat | Potatoes | Barley |

The rotations are represented every year in all six phases, and comparisons of fertility are made by measuring the yields* of the test crops.

* Recorded in *Results of the Field Experiments* issued annually by Rothamsted Experimental Station.

Wheat (Yeoman) was sown on thirty-two 1/44-acre plots in each experiment, at three bushels per acre (2¾ since 1955) late in October, and received a top dressing of nitro-chalk late in April (May 10, 1955). Random samples, each containing the straws with their roots in two adjacent 12-inches of row, were taken each year in July. Six samples per plot in 1952 gave about 21,500 straws, and four, from 1953 onwards, gave about 13,500 straws for examination annually. The straws were examined for eyespot lesions and graded in three categories—none, slight and severe; lesions of sharp eyespot, *Rhizoctonia solani*, and take-all, *Ophiobolus graminis*, on the roots were also recorded.

Eyespot occurred in wheat in all four rotations, but only on few straws each year after three years of grass or lucerne. It was always more prevalent in the arable rotation where the winter wheat was immediately preceded by barley. Slight infections in barley provided enough inoculum for the disease to become prevalent in the succeeding wheat in the years 1954 and 1955, when weather conditions were especially favourable for the disease to spread. (Table 1.)

TABLE 1

*Percentage Wheat Straws with Eyespot Lesions*

| Year | Total Infection | | | | Severe Infection | | | |
|---|---|---|---|---|---|---|---|---|
| | Highfield | | Fosters | | Highfield | | Fosters | |
| | *Ley** | *Arable†* | *Ley** | *Arable†* | *Ley** | *Arable†* | *Ley** | *Arable†* |
| 1952 .. | 1·2 | 19·2 | 1·2 | 7·1 | 0·3 | 12·8 | 0·5 | 5·0 |
| 1953 .. | 1·9 | 6·3 | 3·6 | 6·4 | 0·8 | 2·4 | 1·1 | 2·6 |
| 1954 .. | 0·2 | 21·1 | 14·7 | 90·3 | 0·1 | 12·9 | 6·1 | 69·4 |
| 1955 .. | 4·2 | 43·2 | 9·8 | 71·4 | 2·1 | 22·9 | 4·2 | 48·7 |
| 1956 .. | 0·1 | 0·2 | 0·4 | 0·2 | 0·1 | 0·1 | 0·1 | 0·1 |
| 1957 .. | 1·1 | 5·9 | 5·8 | 8·8 | 0·5 | 3·6 | 2·6 | 4·4 |
| 1958 .. | 1·6 | 10·3 | 1·8 | 8·3 | 0·5 | 5·0 | 0·6 | 4·7 |

* Mean of wheat after lucerne, grazed ley and cut grass.
† With barley, 1952–55; oats, 1956–58.

Lodging occurred on Fosters only in 1954 in the severely infected crop, 80 per cent of which was lodged at harvest. The combined effect of eyespot and lodging probably accounted for the wheat-after-arable crops yielding 13½ cwt per acre less grain than after the leys, a greater difference than that recorded in any other year (Table 2). By contrast, non-parasitic lodging occurred frequently on Highfield in all four rotations. It was severe in 1954 and 1956, and was sometimes more extensive after ley than arable cropping.

As the test crops were planned to measure soil fertility, eyespot was an undesirable complication. Oats, a much less susceptible crop, was substituted for barley in 1955, so that both the arable and the ley-arable rotations now have three years free from wheat or barley. Consequently, in the last three years there has been very little eyespot in any of the four rotations.

Take-all has not developed in these experiments; none was found in wheat after lucerne or grass, and only a trace was recorded in five of the eight wheat plots in the arable rotation on Highfield in 1955.

Sharp eyespot was not usually prevalent although it occurred consistently each year; the percentage of infected straws was similar in all four types of rotation, but on Highfield it ranged in different years from 3·2 per cent to 15·7 per cent with a mean of 7·1 per cent, and on Fosters from 0·5 to 5·8 per cent with a mean of 2·2 per cent. The lesions were seldom deep enough to cause damage.

TABLE 2

*Yield of Grain, cwt per Acre (85 per cent Dry Matter)*

| Year | Highfield | | Fosters | |
|---|---|---|---|---|
| | *Ley** | *Arable†* | *Ley** | *Arable†* |
| 1952 .. | 37·0 | 43·1 | 37·1 | 35·3 |
| 1953 .. | 37·3 | 44·5 | 38·6 | 36·3 |
| 1954 .. | 28·0 | 27·9 | 38·4 | 24·7 |
| 1955 .. | 45·3 | 47·9 | 35·9 | 32·9 |
| 1956 .. | 30·3 | 39·7 | 37·2 | 30·5 |
| 1957 .. | 34·0 | 38·2 | 35·7 | 35·4 |
| 1958 .. | 31·2 | 36·2 | 38·5 | 39·3 |

* Mean of wheat after lucerne, grazed ley and cut grass.
† With barley, 1952–55; oats, 1956–58.

Ley-arable experiments similar to those at Rothamsted are being made on the N.A.A.S. experimental husbandry farms to cover a wide range of conditions representative of English farming. In experiments designed mainly to investigate agronomic problems, the importance of diseases, and particularly of the less obvious soil-borne diseases, is liable to be overlooked. In one year out of four on Fosters at Rothamsted, for example, the grain yield was reduced by 13½ cwt because of eyespot and consequent lodging. The frequency with which such losses occur is very variable, but in the year of their occurrence they greatly affect the trial results. The control of eyespot and other seedborne diseases greatly improves the experiments, and can often be achieved by quite simple alterations in cropping.

# OBSERVATIONS ON SLUG ACTIVITY IN A NORTHUMBERLAND GARDEN

*by* A. R. WHITE

*Royal Grammar School, Newcastle-upon-Tyne*

DURING the period May 1957 to April 1958, with the exception of two weeks in September 1957, regular collections of slugs were made at weekly intervals in a garden at Stocksfield, Northumberland. In all, 7,090 specimens were caught and identified from 112 half-hour collections. The investigation was designed to provide further information on the surface activity of the species encountered under varying weather conditions, and to give general information on the species present and their relative numbers.

The method of sampling was to cover a fixed route passing over representative types of garden vegetation in half an hour. All slugs seen were collected and identified at the end of the collecting period.

Normally, a collection was made thirty minutes after dusk every Saturday evening, a torch of reasonably constant strength being used. This was carried out irrespective of weather conditions so that information was available for all seasons of the year. As it was desirable to obtain more data on relative activity after nightfall, collections were made at hourly intervals from thirty minutes after dusk until dawn the following morning, on the third Saturday evening of each month throughout the year. At the end of each collection a note was made of the temperature, state of the ground and incidence of rain during the collecting period. In order to avoid depleting the natural population unduly, all slugs were returned the next morning to that section of the route from which they had been collected.

The route through the garden was divided into three parts, each part being traversed in ten minutes. The slugs from each part were kept separately at all times. Section A was along the edges of a lawn, examination also being made of the 6 inches of herbaceous border adjoining; B was a strip 2 feet wide through the centre of the vegetable plot, and C was an overgrown pathway on the northern side of a beech hedge—the shadiest and dampest part of the route.

The garden itself is half an acre in extent, 200 feet above sea level, surrounded by copses, orchards and ornamental gardens. The soil is a heavy clay loam, well manured and slightly acid. During the year's observations the garden was tended normally, but no slug deterrent or poison was applied.

## SPECIES OF SLUGS CAUGHT

The range of species was not great, only eight being recorded. They were: *Arion ater* (L.), *Arion rufus* (L.), *Arion hortensis* Fér., *Arion circumscriptus* Johnst., *Agriolimax reticulatus* (Müll.), *Limax maximus* L., *Limax arborum* Bouchard-Chantereaux (syn. *L. marginatus* Müll. 1774) and *Milax budapestensis* (Hazay) (syn. *M. gracilis* (*Leyd.*)). In addition, several specimens of *Arion subfuscus* (Drap.) and one of *Milax sowerbyi* (Fér.) were found, but have been disregarded as they were not taken on the route at collecting time. Identification was by means of the key produced by Barnes and Weil (1944).

Results of the weekly collections half an hour after dark are summarized in Table 1. The data are grouped into monthly totals for four collections except for September (two collections), December and March (five collections). Numbers generally tended to be highest during the spring and were lowest during the winter months. It is to be noted that during January, although four collections were made, no slugs were recovered—frosts on each of the four Saturdays prevented slug activity.

TABLE 1

*Numbers of Slugs Caught Each Month, Half an Hour After Dusk*

| Month | Total No. Slugs Caught (*Percentages in Brackets*) | | | | | | |
|---|---|---|---|---|---|---|---|
| | *Arion ater* | *Arion rufus* | *Arion hortensis* | *Arion circum-scriptus* | *Agrioli-max reticu-latus* | *Milax buda-pestensis* | *All Species* |
| 1957 | | | | | | | |
| May .. | 17 (3·0) | 4 (0·8) | 73 (12·0) | 1 (0·2) | 109 (18·0) | 394 (66·0) | 598 |
| June .. | 24 (7·0) | 6 (1·7) | 33 (10·0) | 1 (0·3) | 52 (16·0) | 213 (65·0) | 329 |
| July* .. | 32 (9·0) | 6 (1·6) | 24 (6·4) | 0 | 89 (24·0) | 217 (59·0) | 368 |
| August .. | 14 (3·3) | 3 (0·7) | 17 (4·0) | 0 | 152 (37·0) | 221 (55·0) | 407 |
| September .. | 17 (11·0) | 4 (2·6) | 5 (3·4) | 0 | 43 (28·0) | 85 (55·0) | 154 |
| October* .. | 16 (4·2) | 1 (0·2) | 25 (5·6) | 0 | 147 (36·0) | 220 (54·0) | 409 |
| November .. | 1 (1·0) | 0 | 20 (19·0) | 1 (1·0) | 36 (34·0) | 48 (45·0) | 106 |
| December .. | 1 (0·5) | 0 | 11 (6·0) | 1 (0·5) | 62 (33·0) | 113 (60·0) | 188 |
| 1958 | | | | | | | |
| January .. | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| February .. | 0 | 0 | 11 (11·9) | 1 (1·1) | 31 (36·0) | 44 (51·0) | 87 |
| March .. | 1 (0·5) | 0 | 43 (20·0) | 6 (2·5) | 52 (23·0) | 121 (54·0) | 223 |
| April .. | 9 (5·0) | 2 (1·0) | 34 (17·0) | 2 (1·0) | 59 (30·0) | 88 (46·0) | 194 |
| Total .. .. | 132 | 26 | 296 | 13 | 832 | 1,764 | 3,063 |

* Single specimens of *Limax arborum* and *L. maximus* were caught in July and October respectively, bringing the total to 3,065 individuals.

## SEASONAL ACTIVITY

Table 1 shows that there were marked differences between the species according to the numbers recovered at different times of the year. For instance, *Arion ater* and *A. rufus* are almost completely inactive during the winter months. *A. circumscriptus* however, shows the reverse trend. At no time a common species, it was not recovered at all during the period from July to October inclusive. The contribution of *A. hortensis* to the monthly catch appears to be consistently greater during the winter than the summer months. Barnes and Weil (1945) found that this species reached its optimum numbers in the autumn, declining in the early months of the year. No such decline is seen in the present figures—indeed it seemed most active during February, March and April. The two common species *Agriolimax reticulatus* and *Milax budapestensis* were always present, although there was a tendency for the former to be less numerous during the early summer months, supporting the findings of Barnes and Weil (1945). It is of interest to note that the dominant species is *M. budapestensis*, as Quick (1949), discussing its distribution, does not record it as having been found further north than Co. Durham.

### INFLUENCE OF TEMPERATURE ON ACTIVITY

Although, for the sake of completeness, searches were made when the temperature was below freezing point, no slugs were recovered, so confirming previous observers that activity ceases completely around 32°F. The way in which general activity is reduced as temperatures fall can be seen from Table 2.

TABLE 2

*Percentages of Each Species Caught in Certain Temperature Ranges*

| Temp. (°F) | No. of Collections | Average No. of Slugs per Collection | Percentage | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | *Arion ater* | *Arion rufus* | *Arion hortensis* | *Arion circumscriptus* | *Agriolimax reticulatus* | *Milax budapestensis* |
| 28–31 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32–35 | 8 | 3 | 0 | 0 | 9 | 0 | 52 | 39 |
| 36–39 | 1 | 35 | 0 | 0 | 12 | 0 | 57 | 32 |
| 40–43 | 10 | 72 | 2 | 0·7 | 14 | 1 | 24 | 58 |
| 44–47 | 5 | 123 | 2 | 0·5 | 12 | 0·5 | 23 | 62 |
| 48–51 | 6 | 84 | 5 | 1 | 10 | 0·2 | 32 | 52 |
| 52–55 | 7 | 108 | 6 | 1 | 6 | 0 | 27 | 60 |
| 56–58 | 4 | 94 | 8 | 1 | 10 | 0 | 28 | 53 |

The average number per collection falls off at temperatures below 40°F indicating a reduced activity generally under colder conditions. Barnes and Weil (1945) suggest that *Agriolimax reticulatus* may be the most resistant to weather changes generally, whilst *Milax budapestensis* and *Arion hortensis* appear to be most susceptible. The falling percentage of *Milax budapestensis* as temperature drops certainly suggests that it is less hardy than *Agriolimax reticulatus* which was the most active species between 40° and 32°F. It is suggested that *Arion hortensis* is just as resistant to cold as *Agriolimax reticulatus:* often when temperatures were between 32° and 33°F, these two species were seen to be active after others had disappeared. This does not agree with Carrick (1942), who found practically no movement in *A. reticulatus* at 10°C, (50°F). Barnes and Weil (1945) suggest that the reduced activity of *Milax budapestensis* in relation to *Agriolimax reticulatus* might be due to the greater depth at which the former remains during frosty weather, the thaw not affecting it as quickly as *A. reticulatus*. This may be so, but as these collections were almost always made under conditions of falling temperature, this difference could also be due to the greater hardiness of *A. reticulatus*.

### THE EFFECT OF FALLING RAIN

By sampling on successive nights, the one fine and the other under rainy conditions, Barnes and Weil (1945) indicate that heavy rain reduces the numbers of slugs active. This finding has been confirmed during the present observations but in a different way. By collecting at hourly intervals a resurgence of activity has been seen on a number of occasions on the cessation of heavy rain. For example, Table 3 gives the catches obtained under the varying conditions of May 21, 1957.

Whilst some increase in activity might be expected two hours or so after dark, comparable collections under uniform conditions at no time gave such rapid increases as those recorded after rain stopped falling.

TABLE 3

*Hourly Catches Under Varying Conditions on May 21, 1957*

| Time (*G.M.T.*) | Rain | *Arion hortensis* | *Agriolimax reticulatus* | *Milax budapestensis* | Other species | All species |
|---|---|---|---|---|---|---|
| 19.30–20.00 .. | Heavy | 17 | 8 | 33 | 7 | 65 |
| 20.30–21.00 .. | Moderate | 10 | 23 | 49 | 7 | 89 |
| 21.30–22.00 .. | Nil | 21 | 51 | 114 | 12 | 198 |
| 22.30–23.00 .. | Nil | 20 | 19 | 95 | 9 | 143 |

At the time of each collection a note was made of the incidence of any rain during the half-hour period. Histograms of the average numbers of the four principal species obtained under varying conditions are given in Fig. 1, and illustrate again the influence of rainfall; and also suggest that *Arion hortensis* is rather less affected than the others by moderate to heavy precipitation.

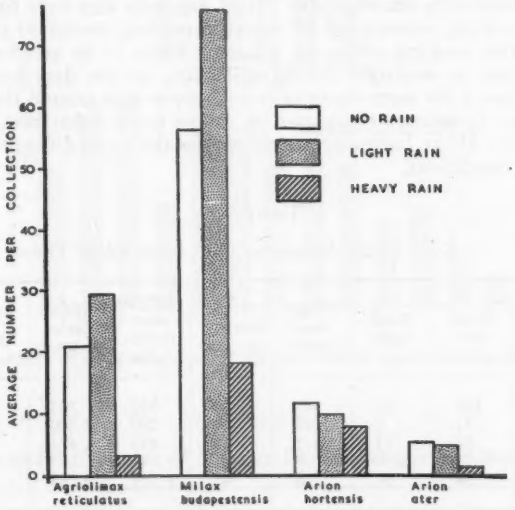


Fig. 1. Effect of falling rain on surface activity of four main species of slugs.

## THE EFFECT OF THE STATE OF THE GROUND

In addition to recording rainfall, ground conditions were classed as: dry, damp, wet or very wet. Of the normal weekly collections thirty-two took place at temperatures of 40°F and above, and these have been examined according to the ground state classification in Table 4. Only the three main species are included as the numbers of others were not sufficient to justify analysis.

The trend towards maximum activity under wet conditions is quite apparent. As a corollary there is an indication, although it does not reach significance level, that extreme conditions are not conducive to great activity.

## THE INFLUENCE OF HABITAT ON SLUG POPULATIONS

As the slugs taken from the three sections of the route were always kept separate, it has been possible to analyse the populations in each area. Table 5

TABLE 4

*Average Number of Slugs Recorded Under Different Ground Conditions*

| | Dry | Damp | Wet | Very Wet | Significant Difference p. 0·05 |
|---|---|---|---|---|---|
| No. of collections .. .. | 3 | 9 | 13 | 7 | |
| *Arion hortensis* .. .. | 7·3 | 5·9 | 11·4 | 10·0 | |
| *Agriolimax reticulatus* .. | 10·7 | 26·3 | 26·2 | 22·1 | |
| *Milax budapestensis* .. .. | 48·3 | 39·8 | 66·2 | 36·7 | |
| Mean .. .. .. .. | 22·1 | 24·0 | 34·6 | 22·9 | 16·01 |

gives the total collections split into the areas where taken and the species. It suggests that *Agriolimax reticulatus* is the dominant species on and around the lawn. Only on the grassland did it outnumber *Milax budapestensis*, the commonest species, whereas in the vegetable patch, regularly dug over for many years, the latter completely outweighed all others, providing almost 80 per cent of the total catch. This striking difference is hardly likely to be accidental, nor is it likely to be due to oversight during collection, as the dark-brown to black *M. budapestensis* is far more easily seen on a green background than is the light brown to grey *Agriolimax reticulatus* by yellow torch light: conversely on the cultivated earth *Milax budapestensis* should be the most difficult to see under poor lighting conditions.

TABLE 5

*Total Catch Separated into Areas where Taken*

| Section | *Arion ater* | *Arion rufus* | *Arion hortensis* | *Arion circumscriptus* | *Agriolimax reticulatus* | *Milax budapestensis* | Other Species | All Species |
|---|---|---|---|---|---|---|---|---|
| Lawn .. | 149 | 32 | 349 | 35 | 952 | 553 | 2 | 2,072 |
| Vegetables .. | 21 | 8 | 264 | 5 | 290 | 2,240 | 1 | 2,829 |
| Pathway .. | 84 | 11 | 155 | 8 | 459 | 1,471 | 1 | 2,189 |
| Total .. | 254 | 51 | 768 | 48 | 1,701 | 4,264 | 4 | 7,090 |

Apart from the two species mentioned above, the numbers have been relatively low throughout the period covered by these observations. The only other deduction that might be drawn is that the lawn edge supported a more varied population, with the species being nearer to equality in numbers than either of the other two parts of the garden sampled regularly.

The dominance of *Milax budapestensis* in the vegetable garden, as compared with the lawn is of interest as it demonstrates how the slug fauna can be quite different on two adjacent areas which have been managed differently.

### ACTIVITY THROUGHOUT THE NIGHT

As collections were begun at hourly intervals after dusk on regular occasions, and all slugs observed were removed, it is likely that the numbers that would normally be active are greater than those actually recovered. The catch in any period represents those that either became active during the preceding hour or strayed on to the route from the adjoining area.

From the three typical histograms in Fig. 2, representing three distinct seasons of the year, it will be seen that numbers caught remained fairly steady until midnight, falling off gradually till dawn. This suggests that the activity really increased up to midnight and probably fell at a lower rate than that indicated.

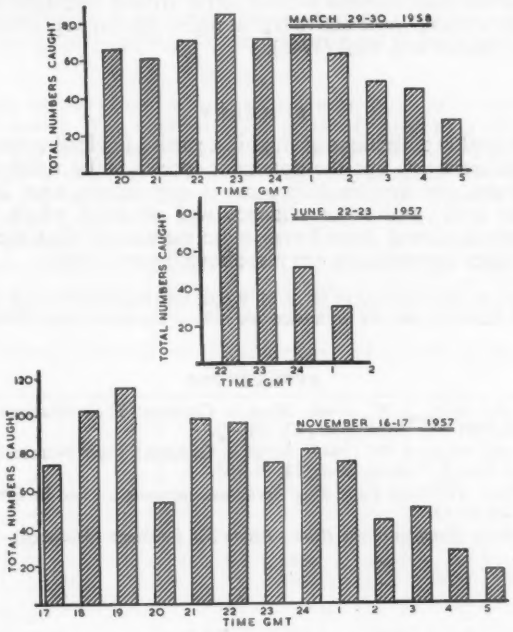


Fig. 2. Total numbers of slugs caught at hourly intervals on nights at three times of the year.

TABLE 6

*Numbers and Percentages of Slugs at Dusk, Midnight and Before Dawn*

| Species | Average No. per Collection | | | Percentage of Total Catch | | |
|---|---|---|---|---|---|---|
| | *Dusk* | *Midnight* | *Dawn* | *Dusk* | *Midnight* | *Dawn* |
| *Arion ater* .. .. .. | 3·5 | 2·6 | 1·7 | 4·0 | 4·0 | 5·0 |
| *Arion rufus* .. .. | 0·9 | 0·4 | 0·0 | 1·0 | 1·0 | 0·0 |
| *Arion hortensis* .. .. | 11·0 | 7·2 | 6·7 | 13·0 | 10·0 | 18·0 |
| *Arion circumscriptus* .. | 0·7 | 0·4 | 0·4 | 1·0 | 1·0 | 1·0 |
| *Agriolimax reticulatus* .. | 19·8 | 14·5 | 6·0 | 24·0 | 19·0 | 17·0 |
| *Milax budapestensis* .. | 46·1 | 47·2 | 21·3 | 57·0 | 65·0 | 59·0 |
| Total .. .. .. | 82·1 | 72·3 | 36·1 | | | |

It is possible, however, that the separate species vary in their behaviour, the component parts of the population giving together the position as outlined above. In order to ascertain whether there was much species variation in activity the

collections after dusk, nearest to midnight G.M.T. and before dawn on nine nights are separated in Table 6.

Although there are no clear-cut trends apparent, from the percentage figures there are suggestions that *Agriolimax reticulatus* becomes less active as the night passes, that *Milax budapestensis* is most active around midnight and that *Arion hortensis* might become more active late at night. Similar suggestions were made tentatively by Barnes and Weil (1945).

SUMMARY

Forty-eight weekly collections of slugs in a garden in Northumberland showed that *Milax budapestensis* was the dominant species under northern conditions on this particular site. Specific differences in populations were found on lawn and cultivated land; and some evidence was obtained which suggests that *Agriolimax reticulatus* and *Arion hortensis* are more hardy than the other species encountered when temperatures are just above freezing point.

I wish to record my indebtedness to Mr. J. H. White, who helped with some of the collections in the middle of the night, and for his advice and help in the preparation of this paper.

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# EFFECT OF METHYL BROMIDE FUMIGATION ON THE POTATO ROOT EELWORM

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THE disinfestation of seed potatoes, to which viable cysts of *Heterodera rostochiensis* Woll, the potato root eelworm, may adhere, is an important problem in relation to international plant health regulations.

The phytotoxicity trials carried out by Lubatti and Blackith (1950) on seed potatoes in this department, showed that lasting damage was caused at concentration-time products (C.T.P.) in excess of 400 mg.h./l. The authors further suggested that seed potatoes were more susceptible when fumigated in the spring than in the autumn: phytotoxic effects were observed at 200 mg.h./1. in spring fumigations, a result similar to that obtained by Goffart (1952).

The nematicidal properties of methyl bromide have been examined by several workers. Franklin (quoted by Lubatti and Blackith, 1950) suggested that a C.T.P. of 500–600 mg.h./l. was necessary to kill all eelworms. Feldmesser, Fassuliotis and Spruyt (1951) showed that there was a complete kill in summer

cysts (99·99 per cent kill in winter cysts) at 250 mg.h./l. Concentration-time products as high as 5888 mg.h./l. were used to eradicate *H. rostochiensis* in burlap bags (Lear and Mai, 1952).

In experiments to determine the nematicidal activity of methyl bromide, the conditions of fumigation were similar to those used by Lubatti and Blackith in their phytotoxicity trials. Several experiments were carried out but as the results were (for the most part) similar, only one experiment is described here.

## METHODS

Soil-free cysts of the potato root eelworm were exposed to methyl bromide in airtight chambers. The concentration of the fumigant to which the cysts were exposed was estimated by sampling the fumigant-laden air at intervals during the experiment, the amount of methyl bromide per sample being determined by the catalytic decomposition method of Lubatti and Blackith (1956). The dosage applied was expressed in terms of the C.T.P., which may be defined as the average concentration of the fumigant in the chamber multiplied by the duration of the fumigation. (The C.T. products are here expressed as mg.h./l. which is for practical purposes equivalent to both oz.h./1,000 cu. ft, the unit normally used in the U.S.A. and g.h./cu.m., the unit used in Europe.)

*The Effect of Methyl Bromide on the Emergence of Larvae of the Potato Root Eelworm*

| | Controls | C.T.P. in Mg.h./l. | | | | |
|---|---|---|---|---|---|---|
| | | *84* | *192* | *288* | *432* | *648* |
| *Source A, Dry Cysts* | | | | | | |
| Larval hatch/50 cysts .. .. | 14,025 | 12,608 | 1,655 | 267 | 7 | 2 |
| Percentage kill .. .. .. | | *10·1* | *88·2* | *98·1* | *99·95* | *99·98* |
| *Source A, Wet Cysts* | | | | | | |
| Larval hatch/50 cysts .. .. | 12,650 | 8,000 | 33 | 0 | 20 | 33 |
| Percentage kill .. .. .. | | *36·7* | *99·7* | *100·0* | *99·8* | *99·7* |
| *Source B, Dry Cysts* | | | | | | |
| Larval hatch/50 cysts .. .. | 11,670 | 6,930 | 2,868 | 1,457 | 1,037 | 1,073 |
| Percentage kill .. .. .. | | *40·6* | *75·4* | *87·5* | *91·1* | *90·8* |
| *Source B, Wet Cysts* | | | | | | |
| Larval hatch/50 cysts .. .. | 11,417 | 3,442 | 10 | 10 | 10 | 8 |
| Percentage kill .. .. .. | | *69·9* | *99·9* | *99·9* | *99·9* | *99·9* |

Batches of fifty cysts were treated in both the dry and wet state, the latter condition being attained by soaking the cysts for one week prior to fumigation when the excess water was removed. Populations of cysts from two sources (A and B) were fumigated, and there were three replications of each treatment. The viability of the cysts after treatment was assessed by hatching the larvae in root diffusate. The hatches were expressed as the mean number of larvae hatching from the replicated batches of cysts. The results are given in the Table.

## DISCUSSION

It is clear that the C.T.P. required to kill all the eelworms (500–1,000 mg.h./l.) is in excess of that which is just not phytotoxic to seed potato tubers. Control measures against cysts adhering to seed potatoes would normally take place while the potatoes were in store awaiting transhipment. In this state the environmental humidity is usually similar to that prevailing in the above experiment where cysts were fumigated in the dry state.

The figure of 500–600 mg.h./l. given by Franklin has therefore been confirmed in this experiment for cysts from source A. However, the increased resistance of the cysts from the other source suggests that there is a differential susceptibility between populations of cysts derived from different sources.

The obvious difference between the two populations is in cyst content; source A were a natural infestation containing 244 eggs per cyst, while the source B cysts were of known age and contained 420 eggs per cyst.

It would appear that the rate of penetration of toxic gases can be correlated with the density of the eggs within the cyst, new full cysts being less permeable than those from a field infestation, the cysts of which have been ruptured and partially emptied. In the absence of any other evidence this is the only explanation which can be offered to account for the observed results.

The results of the above experiment also show that the pretreatment of cysts with water prior to fumigation enhances the penetration of the fumigant to the encysted larvae. This result may be of some practical importance because it has been the practice in recent years (Mabbott, 1956) to wash seed potatoes prior to export to remove soil which may harbour cysts. It may therefore be possible to incorporate a nematicidal treatment during the process of washing to deal with adherent cysts or those developing on the tubers themselves. Research along these lines is in progress.

## SUMMARY

Treatment of cysts with water before methyl bromide fumigation enhances the penetration of the fumigant.

This work has been financed by a grant from the Agricultural Research Council, whose assistance and interest are hereby acknowledged.

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# FURTHER ORCHARD SOURCES OF INFECTION BY *GLOEOSPORIUM* SPP.

*by* R. O. SHARPLES*

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ETIOLOGICAL work on bitter rot disease of stored apples has shown that the main causal organisms, *Gloeosporium perennans* Zeller and Childs and *G. album* Osterw., overwinter in the orchard as tree infections. Both species live as saprophytes on dead stubs, snags and fruiting spurs, while *G. perennans* also invades pruning wounds and other branch injuries to form extensive cankers and dieback lesions. It is now established that, in most orchards, wood infections of these types provide the main sources of conidial inoculum for fruit infection. However, this paper notes two further types of orchard infection which, because of their less frequent occurrence, have hitherto received relatively little attention.

## MUMMIFIED FRUITLET INFECTIONS

The liberation of conidia of *G. album*, during the fruit ripening period, from saprophytic infections on old mummified apples was first recorded by Ogilvie (1935). Recently Guthrie (1957) has recorded both *G. perennans* and *G. album* on mummified fruitlets in Cox and Worcester trees in south-east England. I have also demonstrated the presence of these fungi on old mummified fruitlets in Allington trees at Long Ashton, but in these cases the proportion of the total orchard inoculum arising from such infections was relatively small compared with that originating from saprophytic wood infections.

More recently, samples of mummified fruitlets were obtained from a Hampshire orchard of Cox trees in February 1958 where, although very few saprophytic wood infections of *Gloeosporium* could be found, unusually large numbers of fruitlets were still present overwintering on the trees. After overnight incubation in moist chambers at room temperature, 26 per cent of the mummified fruitlets produced acervuli of *Gloeosporium:* 16 per cent of the fruitlets were found to be infected with *G. perennans*, the remainder being infected with *G. album* (Plate II, 1). In one case, acervuli of both species developed on opposite sides of the same fruitlet. In addition, the conidial stage of *Nectria galligena* was recorded on a further 5 per cent of this material. These mummified fruitlets were firmly attached and would normally have remained on the tree as a source of infection throughout the summer of 1958.

From these observations it is apparent that such mummified fruitlets which, in certain orchards, remain on the trees in considerable numbers throughout the period of fruit development, may constitute an economically important source of *Gloeosporium* infection. In such cases all the old fruitlets should be collected and burned during routine winter pruning.

## LEAF SCAR INFECTIONS

Although cankers caused by *Nectria galligena*, on one-year-old shoots, frequently originate at a leaf scar (Wiltshire, 1921), there have been no previous records of leaf scar infection by *G. perennans*. This apparent difference between two otherwise essentially similar wound parasites of apple wood (Sharples, 1958) was investigated in comparative leaf scar inoculation experiments carried out at Long Ashton in late October, 1957.

The experiments were confined to the 1957 extension shoots of ten-year-old dwarf pyramid Cox trees growing under grass. Twenty shoots were defoliated by gently detaching the petiole at the abscission layer. A drop of spore suspension

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(50,000 conidia per ml) was then placed on each of the exposed leaf scars; there were normally seven to ten suitable scars on each shoot. Half of the defoliated shoots were inoculated with conidia of *G. perennans* while the remainder were inoculated with conidia of *N. galligena*. The viability of the conidia was checked by parallel slide germination tests.

One set of inoculations was made on October 22, 1957, and a second set repeated three days later, shortly before the main period of natural leaf fall. The resulting lesions became evident in the following spring when leaf scar infections were recorded on 20 per cent of the shoots inoculated on both occasions with *N. galligena*, and on 10 per cent of the shoots inoculated on October 22 with *G. perennans*. By the middle of June the leaf scar infections initiated by the latter species had developed into cankers up to 3 cm in length (Plate II, 1b) and were producing acervuli typical of *G. perennans*. None of the second series of inoculations made with *G. perennans* were successful. In all cases, only one of the seven to ten inoculated leaf scars on the infected shoots appeared to be susceptible to either fungus.

In another experiment, snag infections of *G. perennans* were initiated by spore suspension inoculations in mid July 1957 on the current year's extension growth. Although these snags did not exceed 1 cm in length small numbers of acervuli were produced from them later in the same year. In May 1958, sporing lesions of *G. perennans* were recorded on 10 per cent of the shoots bearing distal snag infections. The fresh lesions had clearly originated in leaf scars (Plate II, 1a), being initiated by conidia washed down the shoot from the snag situated approximately 5 cm above.

These results demonstrate that leaf scars on Cox shoots may become infected by *G. perennans* at leaf fall and that by the following summer the lesions will develop into small sporing cankers. Detailed survey work would, however, be required to establish the relative importance of leaf scar infections in the overwintering of *G. perennans* in the orchard. The production of fresh sporing lesions in leaf scars below inconspicuous snag infections illustrates the rapid build-up in orchard infection which may occur under suitable conditions.

## SUMMARY

Saprophytic infections of both *Gloeosporium perennans* and *G. album* on old mummified Cox fruitlets have been found to constitute an economically important orchard source of bitter rot disease. The experimental establishment of leaf scar infections of *G. perennans* is reported.

Thanks are due to Miss N. M. Waugh for valuable experimental assistance, and to Mr. D. E. Aliband and Mr. J. Collyer for the photographs.

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# OCCURRENCE OF TAKE-ALL IN COCKSFOOT AND OTHER GRASSES

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FOLLOWING visits to herbage seed crops in May 1957, J. P. Shildrick of the Seed Production Branch of the Institute drew our attention to the presence of patches of dead plants in a three-year stand of S.143 cocksfoot, *Dactylis glomerata* L., in the Holland division of Lincolnshire. The biggest of these was about 15 yards in diameter but most were 2–4 yards across. Microscopic examination revealed the presence of runner hyphae of *Ophiobolus graminis* (Sacc.) Sacc. over most of the discoloured and rotted roots. The possibility of *Ophiobolus graminis* (Sacc.) Sacc. var. *avenae* E. M. Turner being present cannot be excluded as this has been isolated from several grass species (Smith, 1956). No spore measurements were possible as no perithecia were present. Since previous crops included wheat and barley, but not oats, it is thought probable that *O. graminis*, rather than the oat strain of the fungus, was present. The crop was on a fine sandy loam, a soil well suited for the development of *O. graminis*, but no previous history of take-all was known (Table 1, Field 5). Records of such severe take-all in cocksfoot could not be traced in the literature but Garrett (1941) found, in inoculation tests, that it was moderately susceptible, and more recently Gottlieb, Volosky de Hernandez and Rogers (1958) in similar experiments found South American material to be only slightly susceptible.

TABLE 1

*Previous Cropping in Fields Examined*

| Field | Crop Variety | Age of Crop (*years*) | Previous Cropping | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | *1957* | *1956* | *1955* | *1954* | *1953* | *1952* |
| *1957* | *Holland, Lincs* | | | | | | | |
| 1 | Cocksfoot (S.37) | 3 | C | C | C | P | Bt | W |
| 2 | Cocksfoot (Scotia) | 4 | C | C | C | C | P | Bt |
| 3 | Cocksfoot (S.37) | 2 | C | C | P | Bt | W | O & Pt |
| 4 | Cocksfoot (S.143) | 4 | C | C | C | C | Bn | Pt |
| 5 | Cocksfoot (S.143) | 3 | C | C | C | P | B | W |
| 6 | Cocksfoot (S.143) | 1 | C | B | B | Bb | P | W |
| 7 | Timothy (S.48) | 3 | T | T | T | P | B | W |
| *1958* | *Warwickshire* | | | | | | | |
| 8 | Meadow Fescue (S.215) | 3 | MF | MF | W | F | — | — |
| *1958* | *Worcestershire* | | | | | | | |
| 9 | Oats (S.172 and Blenda) | — | L | L | L | L | L | L |

B = Barley; Bb = Bulbs; Bt = Beet; Bn = Beans; Pt = Potatoes; C = Cocksfoot; F = Fallow; T = Timothy; L = Ley; MF = Meadow Fescue; W = Wheat; O = Oats; P = Peas

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Five other crops of cocksfoot and one of timothy, *Phleum pratense* L., growing in the vicinity were also examined and some patches of dead plants with brown roots and runner hyphae were found in four of them (Table 1, Fields 2, 3, 4 and 5). In one of the cocksfoot crops (Field 6) there were short row lengths of dying plants, but no runner hyphae were found on the roots: while in the timothy crop (Field 7) runner hyphae were found on the roots in small patches of pale yellow plants badly infested with aphids. The cropping histories, ages and varieties of the several crops are shown in Table 1.

In Field 1 the graminaceous members of the appreciable weed population were also examined for take-all. Sterile brome-grass, *Bromus sterilis* L., and perennial rye-grass, *Lolium perenne* L., were severely attacked and had very discoloured roots, but smooth-stalked meadow grass, *Poa pratensis* L., was not infected.

The observations made in 1957 showed that the older crops of cocksfoot had *Ophiobolus graminis* present and were more severely affected than younger ones. Crops of all ages examined in the same locality in 1958 did not show any take-all symptoms. This difference in disease incidence may have been due to climatic factors. The months of April and May, when root activity is high, had exceptionally low rainfall in 1957. This would adversely affect the replacement of roots colonized by the fungus and lead to the typical take-all conditions. In 1958, however, these months had nearly average rainfall so that greater root development, with consequent plant recovery, was possible. Complete recovery did not occur, and in June and July, over the country as a whole, many cases of whiteheads were noted, particularly in cereal crops. Two of these are of special interest.

The first was in a third-year seed crop of S.215 meadow fescue, *Festuca pratensis* Huds., in Warwickshire. This was inspected by W. M. Evans of the Multiplication Branch at the end of June and was found to have a large number of whiteheads, estimated at between 5 and 10 per cent of the total. The roots of affected plants were densely covered with runner hyphae. Garrett (1941) has found meadow fescue to be moderately susceptible in artificial inoculation tests, but again there are no records of naturally occurring outbreaks. The second example was of Blenda and S.172 oats from a Worcestershire farmer. Whiteheads were much in evidence and runner hyphae were present on the roots. This crop followed a six-year cocksfoot-ryegrass-clover ley. Data relating to these two crops (Fields 8 and 9), are included in Table 1. In each case the disease occurred when a grass and a cereal followed one another in the rotation. But in 1957 the cocksfoot and timothy affected were preceded by at least one year of non-cereal crops.

TABLE 2

*Results of Cross Inoculations with* Ophiobolus graminis

| Source of Inoculum | Species Inoculated | | | |
|---|---|---|---|---|
| | *Wheat (Cappelle Desprez)* | *Cocksfoot (S.37)* | *Meadow Fescue (S.215)* | *Barley (Provost)* |
| Cocksfoot (S.37) .. .. .. | + | + | + | No test |
| Meadow Fescue (S.215) .. .. | − | + | − | No test |
| Oats (S.172 and Blenda) .. .. | + | + | + | + |
| Wheat (Cappelle Desprez) .. | + | + | No test | No test |

+ successful infection.

Cross inoculations were made with several of the isolates, using the method described by Garrett (1938) in which seed and infected root material are sown together in a mixture of equal parts of loam and sand. The results of these inoculations are set out in Table 2.

In general, cross inoculation tests were successful, but as only limited amounts of inoculum were available, negative results in Table 2 should not be interpreted as indicating resistance to the disease.

The crop of oats attacked by take-all suffered considerable damage. It is thought probable therefore that the causal organism was *Ophiobolus graminis* (Sacc.) Sacc. var. *avenae* E. M. Turner rather than *Ophiobolus graminis* (Sacc.) Sacc. which attacks wheat but is only weakly parasitic on oats, (Turner, 1940). No perithecia were present on the straw so the spore measurements needed to confirm this observation are, unfortunately, not available. However, the ease with which the oat isolate infected the other cereals and grasses tested is reminiscent of the observations of Turner (1939) and Smith (1956).

## DISCUSSION

The significance, in relation to take-all, of including a grass in the rotation has not been fully realized. In leys containing a mixture of clover and susceptible grasses the take-all declines to a relatively low level and generally it is safe to follow with a cereal crop (Wehrle and Ogilvie, 1955). Buddin and Garrett (1944) found that occasionally a high incidence of take-all occurred in wheat, following a ryegrass-clover ley. This has also been noted in oats (Field 9) after a ryegrass-cocksfoot-clover ley. Cereal crops were not sown after the seed crops recorded in Table 1 but the severity of the symptoms indicates that the fungus would be at a high level. While these workers have concluded that the intrinsic susceptibility of grasses is of little significance in affecting carry-over in leys, the observations here reported show that it is of importance in pure stands grown for seed as a loss of yield may occur.

## SUMMARY

In 1957 patches of dead plants due to take-all were found in several cocksfoot seed crops in the Holland Division of Lincolnshire. A crop of timothy was also affected. Many whiteheads were found in a seed crop of meadow fescue in Warwickshire in 1958. Attention is drawn to the possible significance of seed crops of ley grasses in the carry-over of take-all to cereals.

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# NEW OR UNCOMMON PLANT DISEASES AND PESTS

**Alternaria Leaf Blight of Carrots.** During the late summer and autumn of 1958 reports of a killing of carrot foliage were received from three growers in Norfolk, one in Cambridgeshire, one in Lincolnshire and one in Nottinghamshire. Affected plants were reported to be in patches at first, but later the attack became general and uniformly severe throughout the crop. Up to seven or eight of the outer leaves of each plant were dead and lying on the ground (Plate III, 3), and the inner, more erect, leaves looked ragged owing to the presence of irregular dark brown areas on the edges of the leaflets, with occasional dark flecks elsewhere on the leaves and on the petioles (Plate III, 2). In the centre there was a tuft of healthy green leaves, and it was this leafage that gave the crop a characteristic appearance. The loss of leaf appeared to be affecting the bulking-up of the crop, but in the absence of completely unaffected plants, no sampling comparisons could be made. On examining the leaves a species of *Alternaria* was found sporing freely on the lesions present on the leaflets and petioles. The spores (Plate III, 1) were typical of *Alternaria porri* (Ell.) Ciferri f. sp. *dauci* (Kühn) Neerg. (syn. *A. dauci* (Kühn) Groves and Skolko) having the long filiform beak and size range falling within the limits described for this fungus (Neergaard, P., *Danish Species of Alternaria and Stemphylium*, Copenhagen, 1945, pp. 252–9; Groves, J. W. and Skolko, A. J., *Canad. J. Res.*, 1944, **22**, 217–34). On slightly affected leaves the lesions were usually found at the tips of the leaflets and were of dark brown colour and irregular in shape. The very striking apparent greater susceptibility of the older leaves was previously noted by Hooker (*Phytopathology*, 1944, **34**, 606–12) who showed experimentally that the fungus was definitely more pathogenic to mature leaves.

There is no previous record of this fungus in England and Wales. Unfortunately no samples of seed were available for testing for the presence of this fungus—which is seedborne—nor was information available as to the origin of the seed. There was no suggestion that the attacks were in any way associated with a major element deficiency in the soil, nor did the outbreaks seem to be in any way associated with too frequent cropping with carrots. We presume that the trouble had been brought on by high rainfall and high humidities of the 1958 season.

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